MCR-76-403
NAS8-31789

Volume II

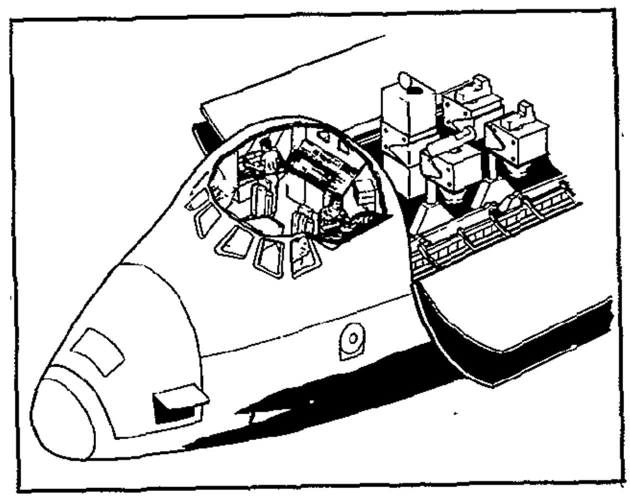
Final Study Report

November 1976

Technical Report

Payload Specialist Station Study

Part I
Preliminary Design Document



MARTIN MARIETTA

MCR-76-403
NAS8-31789

Volume II	Final Study Report	November 1976

TECHNICAL REPORT

PART I
PRELIMINARY DESIGN
DOCUMENT

PAYLOAD SPECIALIST STATION STUDY

Approved

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FOREWORD

This document was prepared by the Martin Marietta Corporation, Denver Division, for the National Aeronautics and Space Administration, Marshall Space Flight Center. This volume forms a part of the Final Study Report for Contract NAS8-31789, *Payload Specialist Station Study*, completed under the technical direction of Mr. William Lucero, Contracting Officer's Representative, MSFC.

The following documents form the complete Final Study Report:

Volume I		Executive Summary
Volume II		Technical Report
	Part I	Preliminary Design Document
	Part II	Contract End Item Specifications (Part I)
	Part III	Program Analysis and Planning for Phase C/D
Volume III		Program Study Cost Estimates
	Part I	Work Breakdown Structure
	Part II	Cost Data

CONTENTS

ABBREVIATIONS AND ACRONYMS

AFD	Aft flight deck
AMPS	Atmospheric, Magnetospheric, and Plasmas in Space
ATP	Authorization to proceed
BESS	Biomedical Experiment Scientific Satellite
CCD	Core control and displays
CCTV	Closed circuit television
C&D, C/D	Controls and displays; procurement phases C and D
CDR	Critical design review
CEI	Contract end item
COR	Contracting Officer's Representative
CPCEI	Computer program contract end item (specification)
CRT	Cathode ray tube
DBC	Data bus coupler
D/D	Design and development
DDU	Data display unit
DDT&E	Design, development, test, and engineering
DEU	Display electronics unit
DOD	Department of Defense
DSSM	Dedicated Solar Sortie Mission
DUST	Deep Sky UV Survey Telescope
DWS	Disaster Warning Satellite
EOS	Earth Observatory Satellite
ET	Event timer
EU	Electronics unit
FDA	Fault detection and annunciation
FSMS	Foreign Synchronous Meteorological Satellite
FY	Fiscal year
G&A	General and administrative
GFE	Government furnished equipment
GN&C, GNC	Guidance, navigation, and control

GPC	General purpose computer (Orbiter)
GRS	Gravity Relativity Satellite
GSE	Ground support equipment
ICD	Interface Control Document
IND	Indicator(s)
I/O, IOP	Input/output processor
IPS	Instrument pointing system (Spacelab)
I/S	Interconnecting station (Spacelab)
IUS	Interim Upper Stage
KB	Keyboard
Kw	Kilowatt
LCMS	Low cost modular spacecraft (MMS)
LDEF	Long Duration Exposure Facility
LED	Light emitting diode
LH_2	Liquid hydrogen
LO_2	Liquid oxygen
Mb	Megabit (10^6)
MDM	Multiplexer-demultiplexer
MFDS	Multi-function Display System
MMS	Multi-mission Modular Spacecraft
MMSE	Multi-use Mission Support Equipment
MPC	Manual pointing controller
MPM	Mini-pointing mount
MS, MSS	Mission station, mission specialist, mission specialist station
NSP	Network signal processor
OOS	On-orbit station
PCMMU	Pulse code modulation master unit
PCS	Payload control supervisor
PDI	Payload data interleaver
PDR	Preliminary design review

PIDA	Payload installation and deployment assembly
PL, P/L	Payload
PS, PSS	Payload station, payload specialist, payload specialist station
PSP	Payload signal processor
RAU	Remote acquisition unit
SC	Spacecraft
SD	Slewed digital
SE&I	Systems engineering and integration
SIMS	Shuttle Imaging Microwave System
SIPS	Small Instrument Pointing System
SIRTF	Spacelab Infrared Telescope Facility
SL	Spacelab
SLC	Spacelab computer
SPHINX	Space Plasma High Voltage Interaction Experiment Satellite
SM	Systems management
SMM	Solar Maximum Mission
SS, S/S	Subsystem
SSEI	Selectable switch and event indicator
ST	Space Telescope
STE	Space test equipment
STP	Space test project
STS	Space Transportation System
SUOT	Spacelab Ultraviolet Optical Telescope
SW, S/W	Software
TOBE	Teleoperator Orbiter Bay Experiment
TP	Twisted pair
TSP	Twisted shielded pair
WBS	Work breakdown structure

VOLUME II - TECHNICAL REPORT, PART I - PRELIMINARY DESIGN DOCUMENT

This document presents the results of the Payload Specialist Station Study (NAS8-31789) and describes the specific task activities conducted to produce those results. The purpose of the study was to define an optimum aft flight deck (AFD) controls and displays (C&D) configuration concept for payload operations within the Shuttle Orbiter. The concept derived satisfies the large majority of identified payload C&D requirements through the 1980's, is cost effective, and utilizes existing technology.

The results of this study are directly applicable to Phase C/D activities. Part I CEI specifications, programmatic analyses, Phase C/D program definition and schedules, and economic analyses have been completed; and estimated Phase C/D costs have been identified. These results are discussed in separate volumes of this report, as listed below:

Volume I - Executive Summary;
Volume II, Part II - Part I CEI Specifications;
Volume II, Part III - Program Analysis and Planning for Phase C/D;
Volume III, Part I - Work Breakdown Structure;
Volume III, Part II - Program Study Cost Estimates.

The AFD control and display concept derived by this study is defined in this report in the form of panel layouts, CEI specifications, and programmatics for Phase C/D. The study included seven tasks:

Task I, Derive Payload Control and Display Requirements;
Task II, Perform Functional Analyses;
Task III, Perform System Synthesis;
Task IV, Perform Trade Studies;
Task V, Perform Preliminary Design;
Task VI, Provide Programmatics;
Task VII, Provide Data Format.

The details of tasks I through V and VII are discussed in Sections 2.0 through 6.0 of this report. Programmatics (Task VI) are detailed in separate volumes of this final report.

1.0 SUMMARY DESCRIPTION - AFD C&D CONCEPT

Figure 1-1 shows the Orbiter aft flight deck within which the AFD C&D concept is configured. Payload-dedicated panel areas are indicated in the figure, as are the Orbiter controls and displays which payloads can utilize during on-orbit operation. Figure 1-2 shows a schematic representation of the controls and displays contained within the core AFD concept derived in this study. The core concept utilizes Spacelab government furnished equipment (CRT/keyboard at R12, instrument pointing system backup C&D, experiment and subsystem remote acquisition unit, power distribution box, and interconnect stations). This concept can be implemented by either of two AFD panel layouts, as shown in the composites depicted in Figure 1-3 and 1-4. The first layout utilizes STS program qualfied hardware at payload station (PS) panels L10 and L11, and the second utilizes new development hardware at those panels. The firgures identify the C&D components to be acquired in Phase I or Phase II of the program procurement cycle (see Section 2.0 of the Executive Summary [Volume 1]). The core concept also utilizes a set of multi-use mission support equipment (MMSE) which comprises all of panel L12 and portions of panels L11 and A7. The rationale for the use of MMSE and the analyses conducted to identify the MMSE is discussed in Section 5.0 of this report. Although the layouts are functionally identical, the new development option offers advantages over the STS option in overall program costs, electrical power requirements, and Spacelab impacts. In addition, the STS equipment option requires the CRT/keyboard at panel L10 be supplied as GFE, whereas the new development option provides for the design of the entire PS (L10, L11, L12) as a complete unit.

Section 6.0 in this volume describes the preliminary design of these panels in more detail, and identifies the primary interfaces between the core C&D and Orbiter or Spacelab systems. Power and wiring utilization by the core C&D is also described, and a weight summary is provided.

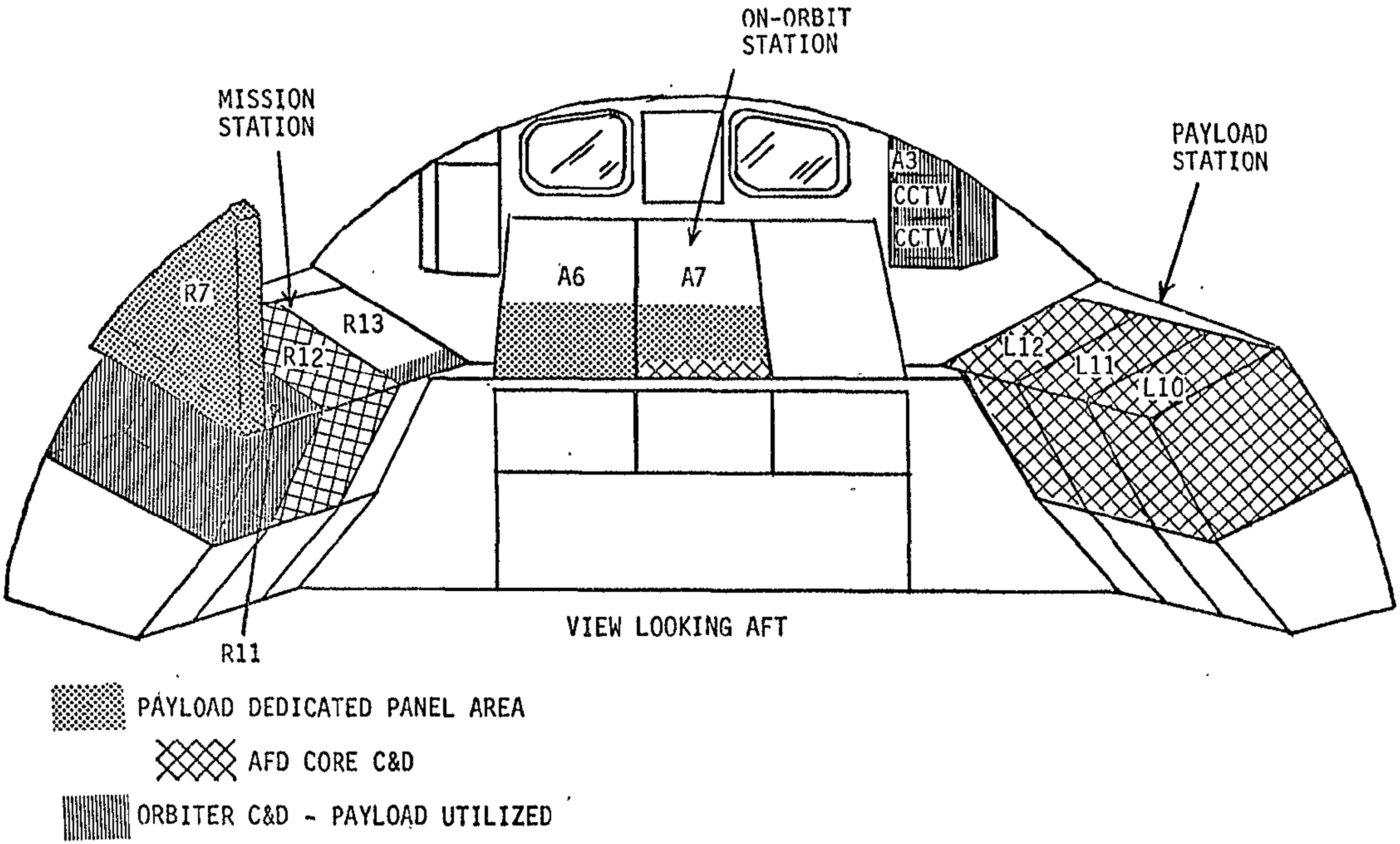

Figure 1-1 Orbiter AFD C&D Utilization

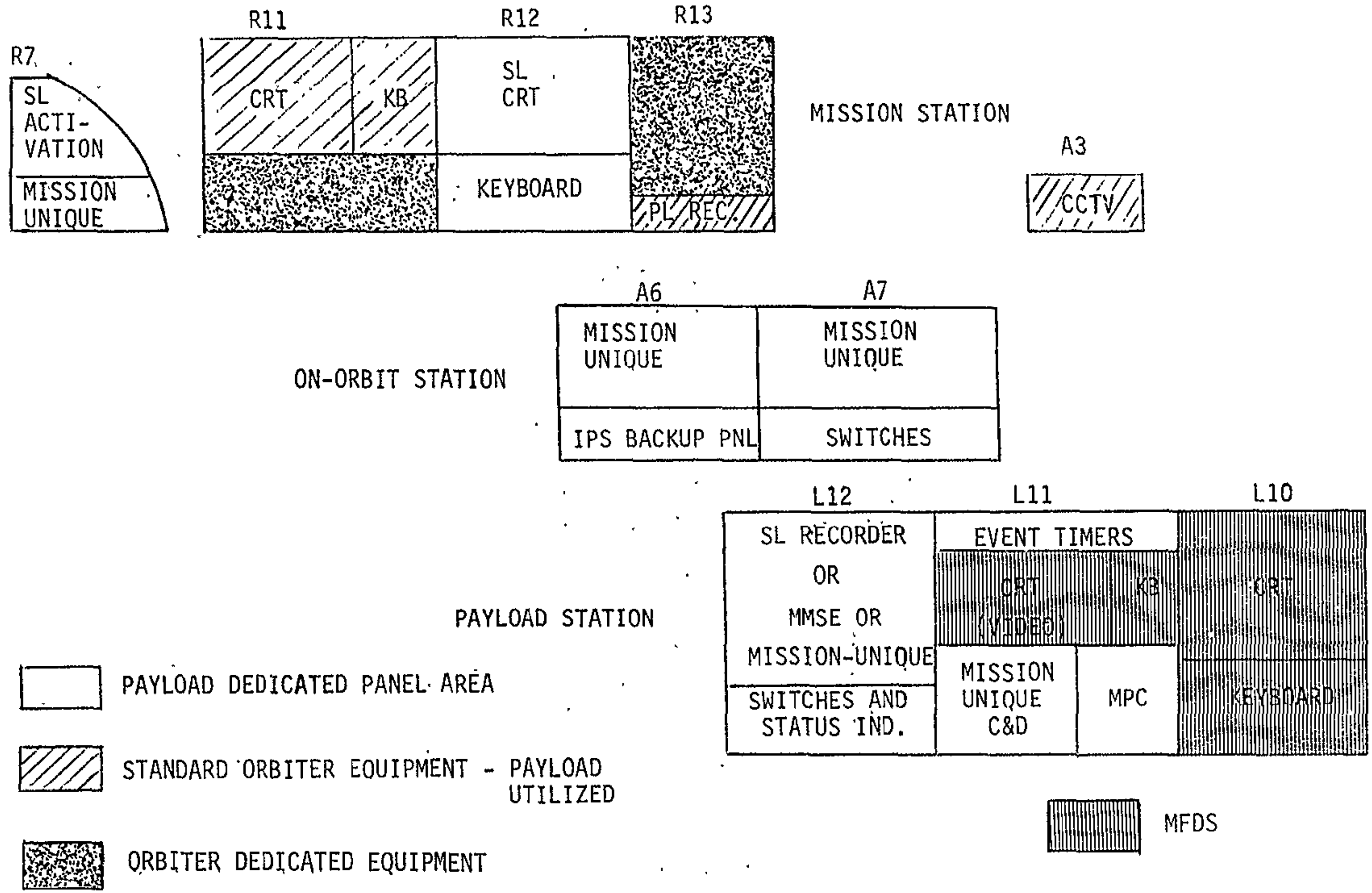

Figure 1-2 AFD C&D Schematic

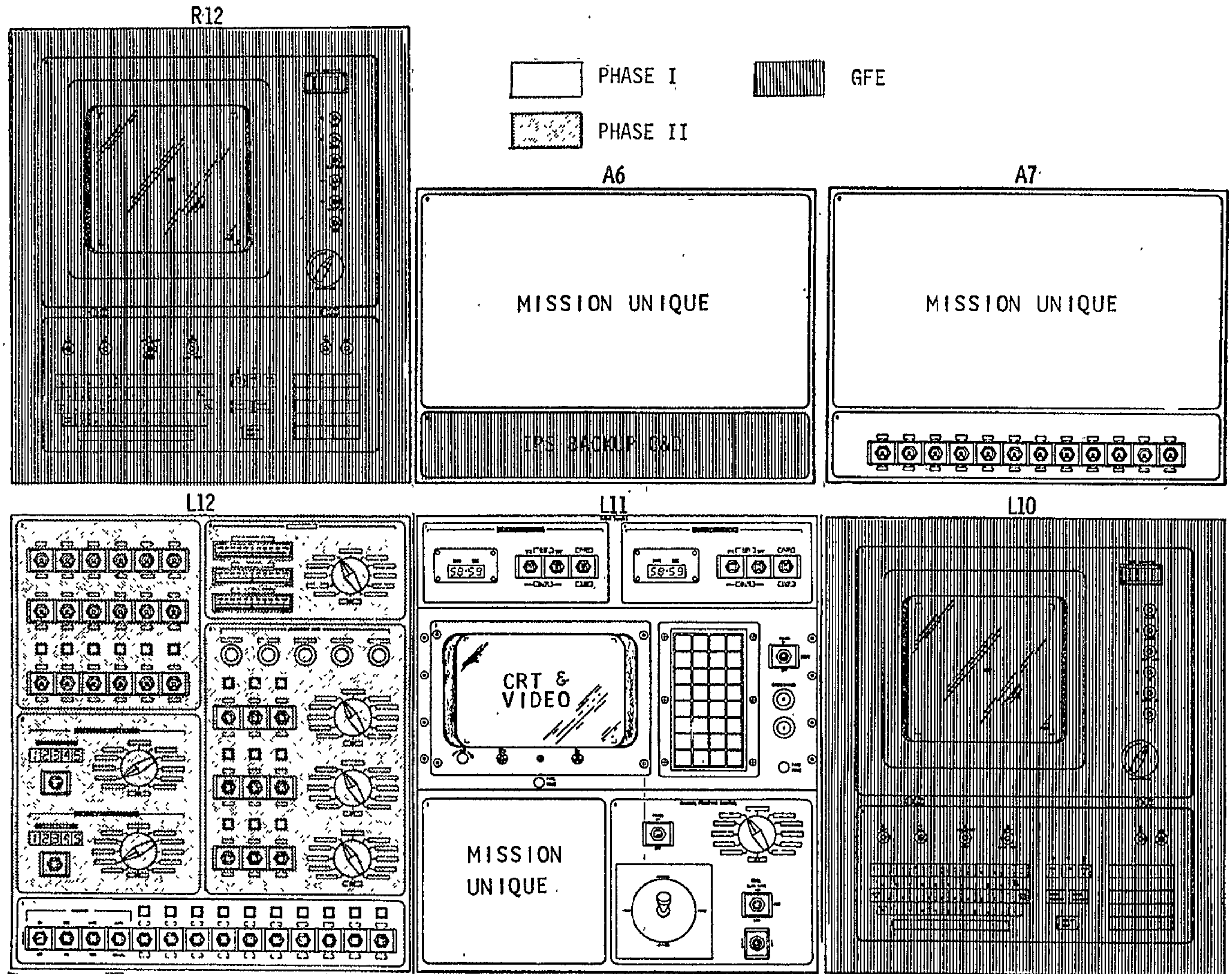

Figure 1-3 AFD Core C&D Concept (STS Hardware)

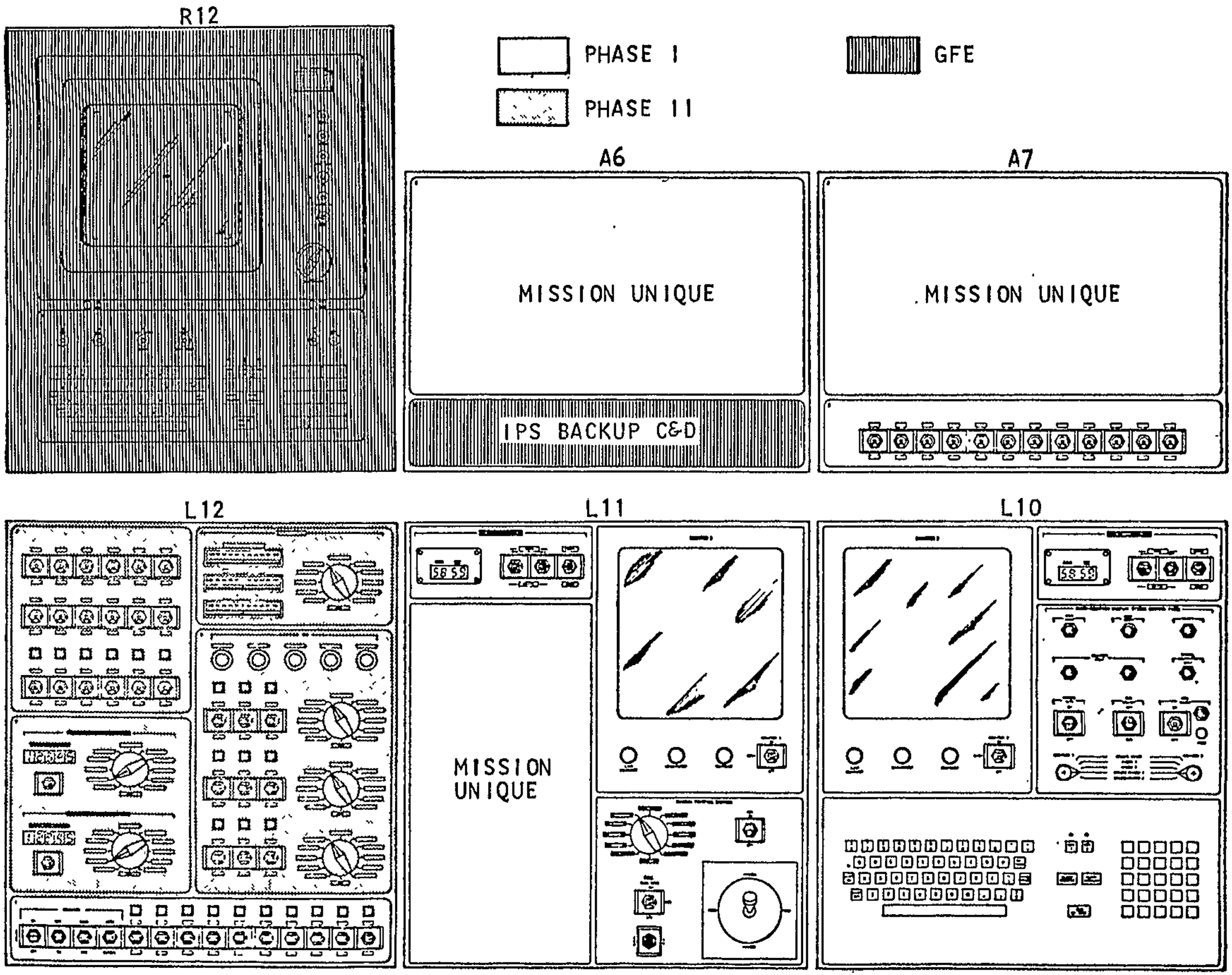

Figure 1-4 AFD Core C&D Concept (New Development Hardware)

2.0 PAYLOAD CONTROLS AND DISPLAYS REQUIREMENTS

2.1 Documentation - The documentation activities covered the six categories listed below:

1) STS Program;
2) Carrier Baselines;
3) Mission Models;
4) Previous MMC Study Results;
5) Payload Descriptions;
6) Related Contractor Studies.

2.1.1 STS Program Documentation - Current STS program documentation related to payload C&D requirements were obtained from MSFC and JSC central files, and the study COR.

Typical documents included--1) JSC series, Volume XIV, 2) Summarized NASA Payload Descriptions, Level A Data, 3) Payload Descriptions, Volume II--Books 1 and 2, Level B Data, 4) Safety Policy Manual, and 5) the latest issues of the Spacelab Design Review Documents pertaining to interfaces, hardware, and subsystems.

2.1.2 Carrier Baselines - Current baseline documents providing descriptions of the Orbiter and Spacelab carriers were obtained. Typical documents consisted of--1) Orbiter crew station reviews- 2) Orbiter Definition Handbook, 3) Orbiter Software Specifications, 4) Spacelab Payload Accommodations Handbook, and 5) Spacelab Interface and Software Specifications.

2.1.3 Mission Model - Updated mission model data was acquired and these included--1) data on the first three years' flights provided by MSFC, 2) data available through MMSE contract on the first three years (NASA/Headquarters), and 3) 572 Yardley Traffic Model (1983-1991).

2.1.4 Previous MMC Study Results - The library documents acquired during the previous MSFC/MMC controls and displays study, *Integrated Control/Display Station for Teleoperator and Experiments*, (NAS8-31147) were directly applied into the selection of the candidate payloads.

2.1.5 Payload Descriptions - Additional payload documentation was acquired for those payloads that lacked detailed descriptions, or current updated program data was released. These documents were obtained through personal contacts with the payload community.

Typical documentation included the following payloads--1) LDEF, 2) STORMSAT, 3) SPHINX, and 4) Space Test Program. The acquisition of the various documents for each of the categories listed above enabled an extensive library source to be developed.

2.2 STS Program Payloads - The Space Transportation System (STS) Program payloads as described in the two NASA documents--"Summarized NASA Payload Descriptions, Level A Data," and "Payload Descriptions, Volume II--Books 1 and 2, Level B Data" number approximately 250 payloads. These payloads are grouped under the eleven disciplines listed below.

Payload Discipline

- Astronomy
- High Energy Astrophysics
- Solar Physics
- Atmospheric and Space Physics
- Earth Observations
- Earth and Ocean Physics
- Space Processing Applications
- Life Sciences
- Space Technology
- Communications and Navigation
- Planetary

2.3 Payload Selections - To effectively analyze every payload for its control and display requirements and to contact each payload directly for detail information was beyond the scope of this study. The approach undertaken was to review the 250 payloads, and from their objectives and experiment hardware equipment described in the above documents, reduce the number

of payloads to a quantity that could be effectively analyzed for their control and display requirements. The representative payloads were selected in such a way that they bounded all 250 payloads.

Utilizing this type of approach enabled the candidate list for the study payloads to be reduced to the twenty-eight listed on Tables 2-1 and 2-2. As noted on these tables, 10 of the 11 payload discipline groups are included in the candidate payloads. The only discipline not included is the Earth and Ocean Physics, however the payloads under this discipline were amply evaluated by the three Earth Observation payloads, i.e., the Earth Observatory Satellite, Shuttle Imaging Microwave System, and Storm Satellite.

The correlation of the STS program payloads to the twenty-eight study payloads was completed and the results are presented on Table 2-3. A representative example is the shaded column which lists twenty-two payloads (checkmarks) and were evaluated by the One-Meter Spacelab UV Optical Telescope (SUOT). The SUOT payload includes the baseline UV telescope and four focal plane instruments.

2.3.1 Payload Types - The candidate payloads were further analyzed by types. The type categories included the groups listed below for the sortie and free-flyer payloads:

Payload	Type Category
1. Sortie	• Spacelab Module
	• Spacelab Pallet
	• Bay Mounted
	• Partial Cargo
2. Free-Flyer	• Partial Cargo
	• Full Cargo
	• With IUS
	• Without IUS
	• Retrieved

Table 2-1 Recommended Payloads - Pallet and Spacelab Module Mounted

PALLET	SPACELAB MODULE
1. <u>Astronomy</u> • Spacelab IR Telescope Facility (SIRTF) (AS-01-S) • Deep Sky UV Telescope (AS-03-S) • Spacelab UV Optical Telescope (SUOT) (AS-04-S) 2. <u>Solar Physics</u> • Dedicated Solar Sortie Mission (DSSM) (SO-01-S) 3. <u>High Energy</u> • Magnetic Spectrometer (HE-15-S) 4. <u>Earth Observations</u> • Shuttle Imaging Microwave System (SIMS) (EO-21-S) 5. <u>Space Processing</u> • Automated Levitation (SP-13-S) • Automated Furnace/Levitation (SP-15-S) 6. <u>Life Sciences</u> • Teleoperator Orbiter Bay Experiment (TOBE) (LS-04-S) <u>Spacelab</u> • Spacelab 2	<u>Spacelab</u> • Spacelab 1 • Spacelab 3 6. <u>Life Sciences</u> • Life Sciences Mini-Lab (LS-09-S) 7. <u>Atmospheric and Space Physics</u> • AMPS (AP-06-S)

NOTE: Digits 1 through 7 are payload disciplines.

Table 2-2 Recommended Payloads--Automated With or Without IUS

WITH IUS	WITHOUT IUS
• Interim Upper Stage (IUS)	2. Solar Physics
8. Communications and Navigation	• Solar Maximum Mission (SMM) (SO-03-A)
• Disaster Warning Satellite (DWS) (CN-54-A)	4. Earth Observations
• Foreign Synchronous Meteorological Satellite (FSMS) (EO-57-A)	• Earth Observatory Satellite (EOS) (EO-08-A)
• DOD - Classified Payload	6. Life Sciences
• Storm Satellite (STORMSAT) (EO-15-A)	• Biomedical Experiment Scientific Satellite (BESS) (LS-02-A)
9. Space Technology	7. Atmospheric and Space Physics
• Space Plasma High Voltage Interaction Experiment Satellite (SPHINX) (ST-02/03-A)	• Gravity and Relativity Satellite (GRS) (AP-04-A)
10. Planetary	9. Space Technology
• Jupiter Orbiter Probe (PL-13-A)	• Space Telescope (ST) (AS-01-A)
· Space Test Project (STP)	• Long Duration Exposure Facility (LDEF) (ST-01-A)

NOTE: Digits 2 through 10 are payload disciplines

Table 2-4 and 2-5 list the results of this analysis respectively for the sortie and free-flyer payloads. The results for the Sortie payloads illustrate the majority of the payloads--1) utilize the Spacelab pallets, 2) are partial cargos, 3) require on-orbit control. The results for the free-flyer payloads (Table 2-5) exhibited primarily the following type categories--1) partial cargo, and 2) an almost even division with IUS and without IUS.

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Table 2-3. Correlation of Candidate Payloads to STS Program Payloads

SSPD PAYLOAD	PSS STUDY-REPRESENTATIVE P/L MODEL	SOLAR MAXIMUM MISSION (SMM) (SO-03-A)	GRAVITY & RELATIVITY SATELLITE (GRS) (AP-04-A)	BIOMEDICAL EXPERIMENT SCIENTIFIC SATELLITE (BESS) (LS-02-A)	EARTH OBSERVATORY SATELLITE (EOS) (EO-08-A)	SPACE TELESCOPE (AS-01-A)	STORMSAT (EO-15-A)	SPHINX (ST-02/03-A)	PIONEER JUPITER ORBITER PROBE	LONG DURATION EXPOSURE FACILITY (LDEF) (ST-01-A)	DISASTER WARNING SATELLITE (DWS) (CN-54-A)	FOREIGN SYNCHRONOUS METEOROLOGICAL SATELLITE (FSMS) (EO-57-A)	SPACE TEST PROJECT (STP)	INTERIM UPPER STAGE (IUS)	DOD/IUS-CLASSIFIED PAYLOAD	TELEOPERATOR ORBITER BAY EXPERIMENT (LS-04-S)	[illegible]	SHUTTLE IR TELESCOPE FACILITY (AS-01-S)	DEEP SKY UV TELESCOPE (AS-03-S)	MAGNETIC SPECTROMETER (HE-15-S)	SHUTTLE IMAGING MICROWAVE SYSTEM (EO-21-S)	AUTO LEVITATION (SP-13-S)	AUTO FURNACE/LEVITATION (SP-15-S)	DEDICATED SOLAR SORTIE MISSION (SO-01-S)	AMPS (AP-06-S)	SPACELAB 1 (NASA/ESA)	SPACELAB 2	LIFE SCIENCES LAB (LS-09-S)	SPACELAB 3
SORTIE PAYLOADS																													
AS-01-S	1.0m SHUTTLE IR TELESCOPE FACILITY																	√											
AS-03-S	DEEP SKY UV SURVEY TELESCOPE																		√										
AS-04-S	1m DIFFRACTION LIMITED UV OPTICAL TELESCOPE																√												
AS-05-S	VERY WIDE FIELD GALACTIC CAMERA																		√										
AS-07-S	COMETARY SIMULATION																√												
AS-09-S	30m IR INTERFEROMETER																√								√				
AS-10-S	ADV. XUV TELESCOPE																√	√											
AS-12-S	METEOROID SIMULATION																√								√				
AS-13-S	SOLAR VARIATION PHOTOMETER																							√					
AS-14-S	1.0m UNCOOLED IR TELESCOPE																	√											
AS-15-S	3.0m AMBIENT TEMPERATURE IR TELESCOPE																	√											
AS-18-S	1.5 km IR INTERFEROMETER																√								√				
AS-19-S	SELECTED AREA DEEP SKY SURVEY TELESCOPE																		√										
AS-20-S	2.5m CRYOGENICALLY COOLED IR TELESCOPE																	√											
AS-31-S	COMBINED AS-01, -03, -04, -05-S																√	√	√										
AS-32-S	COMBINED AS-01, -04, -05-S																√	√	√										
AS-41-S	SCHWARTZSCHILD CAMERA																√		√										
AS-42-S	FAR UV ELECTRONOGRAPHIC SCHMIDT CAMERA/SPECTROGRAPH																√		√										
AS-43-S	UCB BLACK BRANT PAYLOAD																√		√										
AS-44-S	XUV CONCENTRATOR/DETECTOR																√			√									
AS-45-S	PROPORTIONAL COUNTER ARRAY																			√									
AS-47-S	ATTACHED FAR IR SPECTROMETER																	√											
AS-48-S	ARIES/SHUTTLE UV TELESCOPE																√		√										
AS-49-S	FIRST UCB BLACK BRANT PAYLOAD																√								√				
AS-50-S	COMBINED UV/XUV MEAS (AS-04, -10-S)																√												
AS-51-S	COMBINED IR PAYLOAD (AS-01, -15-S)																	√											
AS-54-S	COMBINED UV PAYLOADS (AS-03, -04, -49-S)																√		√	√									
AS-61-S	ATTACHED FAR IR PHOTOMETER (WIDE FOV)																	√											
AS-62-S	COSMIC BACKGROUND ANISOTROPY																			√									
AS-63-S	SORTIE MEDIUM APERTURE OPTICAL TELESCOPE																												
AS-64-S	UV PHOTOMETER AND SPECTROGRAPH																√												
AS-65-S	FAINT SURFACE PHENOMENA (AS-701)																√												
AS-66-S	LYMAN BETA IMAGING (AS-702)																√												
HE-11-S	X-RAY ANGULAR STRUCTURE																										√		
HE-12-S	HIGH INCLINATION COSMIC RAY SURVEY																			√							√		
HE-13-S	X-RAY/GAMMA RAY PALLET																			√									
HE-14-S	GAMMA RAY PALLET																			√									
HE-15-S	MAGNETIC SPECTROMETER																			√									
HE-16-S	HIGH ENERGY GAMMA-RAY SURVEY																			√									
HE-17-S	HIGH ENERGY COSMIC RAY STUDY																			√									
HE-18-S	GAMMA-RAY PHOTOMETRIC STUDIES																			√									
HE-19-S	LOW ENERGY X-RAY TELESCOPE																√			√									
HE-20-S	HIGH RESOLUTION X-RAY TELESCOPE																√			√									
HE-21-S	ANTI-PROTON MEASUREMENTS																			√									
HE-22-S	LIQUID X DETECTOR																	√		√									
HE-23-S	HIGH SENSITIVITY MEDIUM ENERGY GAMMA RAY SURVEY																			√									
HE-25-S	TRANSITION RADIATION DETECTOR (HE-701)																			√									
HE-26-S	GRADED CERENKOV DETECTOR (HE-702)																			√									
HE-27-S	HIGH ENERGY GAMMA RAY DETECTOR (HE-703)																			√									
SO-01-S	DEDICATED SOLAR SORTIE MISSION (DSSM)																							√					
SO-11-S	SOLAR FINE POINTING PAYLOAD																							√					
SO-12-S	ATM SPACELAB																							√					
SO-13-S	FAR INFRARED TELESCOPE, AMBIENT TEMPERATURE																	√						√					
SO-14-S	FLARE COARSE MONITORING PACKAGE																							√					
SO-15-S	SOLAR ACTIVITY EARLY PAYLOAD																							√					
SO-16-S	SOLAR FLARE DETAILED X-RAY STRUCTURE																							√					
SO-17-S	SOLAR ACTIVITY GROWTH PROCESSES (SO-703)																										√		
SO-18-S	SOLAR ATMOSPHERIC WAVE PROPAGATION																							√					
SO-19-S	PHYSICS OF FLARING BRIGHT POINTS																							√					
SO-20-S	DENSITY FROM BeI-LIKE IONS																							√					
SO-21-S	CORONAL DYNAMICS																							√					
SO-22-S	SOLAR FLARE PLASMA FLOW (SO-701)																							√					
SO-23-S	DETAILED X-RAY STRUCTURE OF SOLAR FLARES (SO-702)																							√					
AP-06-S	ATMOSPHERIC, MAGNETOSPHERIC, AND PLASMAS IN SPACE (AMPS)																								√				
AP-08-S	LIDAR SYSTEM (AP-701)																									√			
AP-09-S	ELECTRON ACCELERATOR (AP-702)																									√			
AP-10-S	CHEMICAL RELEASE (AP-703)																								√				
AP-11-S	DIAGNOSTIC PAYLOAD (AP-704)																								√				
AP-12-S	TADS (AP-705)																								√				
EO-01-S	ZERO-G CLOUD PHYSICS LABORATORY (EO-701)																									√			
EO-05-S	SHUTTLE IMAGING MICROWAVE SYSTEM (SIMS B)																				√								
EO-06-S	SCANNING SPECTRORADIOMETER																				√								
EO-07-S	ACTIVE OPTICAL SCATTEROMETER																				√					√			
EO-09-S	HIGH RESOLUTION OZONE MAPPER																				√								
EO-11-S	SHUTTLE CALIBRATION FACILITY																				√				√	√			
EO-12-S	ACTIVE AND PASSIVE CLOUD RADIANCE																				√					√			
EO-13-S	MICROWAVE LIMB SOUNDER																				√					√			
EO-15-S	STANDARD EARTH OBSERVATIONS PACKAGE																				√					√			
EO-16-S	ATMOSPHERIC X-RAY EMISSION EXPT.																√								√				
EO-17-S	SPECIALIZED MULTISPECTRAL IMAGING SYSTEM																				√								
EO-18-S	METEOROLOGY RADAR FACILITY (EO-702)																								√	√			
EO-19-S	MARK II INTERFEROMETER - SOLAR (EO-703)																										√		
EO-20-S	EARTH RESOURCES SHUTTLE IMAGING RADAR (EO-704)																				√								
EO-21-S	SHUTTLE IMAGING MICROWAVE SYSTEM (SIMS A)																				√								
EO-22-S	MARK II INTERFEROMETER - EARTH																				√						√		
OP-02-S	MULTIFREQUENCY RADAR LAND IMAGERY (OP-702)																				√				√				
OP-03-S	MULTIFREQUENCY DUAL POLARIZED MICROWAVE RADIOMETRY (OP-703)																				√				√				
OP-04-S	MICROWAVE SCATTEROMETER																				√								
OP-05-S	MULTISPECTRAL SCANNING IMAGERY																				√						√		
OP-06-S	LASER ALTIMETER/PROFILOMETER EXPERIMENT																				√					√			
OP-08-S	MULTIFREQUENCY PROPAGATION EXPT																				√					√			
OP-09-S	LASER RANGING DEVICE																				√					√			
OP-13-S	OCEAN WAVE SPECTRUM MEASUREMENT																				√					√			
OP-14-S	PRECISION LASER RANGING SYSTEM (OP-701)																				√					√			
OP-16-S	VECTOR GEOMAGNETIC FIELD MEASUREMENT																				√				√				
SP-01-S	SPA NO. 1 - BIOLOGICAL (MANNED) (B+C)																					√				√			
SP-02-S	SPA NO. 2 - FURNACE (MANNED) (F+C)																					√				√			

FOLDOUT FRAME 3

Table 2-3 Correlation of Candidate Payloads to STS Program Payloads (Continued)

SSPD PAYLOAD	FSS STUDY REPRESENTATIVE P/L MODEL	SOLAR MAXIMUM MISSION (SMM) (SO-03-A)	GRAVITY & RELATIVITY SATELLITE (GRS) (AP-04-A)	BIOMEDICAL EXPERIMENT SCIENTIFIC SATELLITE (BESS) (LS-02-A)	EARTH OBSERVATORY SATELLITE (EOS) (EO-08-A)	SPACE TELESCOPE (AS-01-A)	STORMSAT (EO-15-A)	SPHINX (ST-02/03-A)	PIONEER JUPITER ORBITER PROBE	LONG DURATION EXPOSURE FACILITY (LDEF) (ST-01-A)	DISASTER WARNING SATELLITE (DWS) (CN-56-A)	FOREIGN SYNCHRONOUS METEOROLOGICAL SATELLITE (FSMS) (EO-57-A)	SPACE TEST PROJECT (STP)	INTERIM UPPER STAGE (IUS)	DOD/IUS-CLASSIFIED PAYLOAD	TELEOPERATOR ORBITER BAY EXPERIMENT (LS-04-S)	IM UV TELESCOPE (AS-04-S)	SHUTTLE IR TELESCOPE FACILITY (AS-02-S)	DEEP SKY UV TELESCOPE (AS-12-S)	MAGNETIC SPECTROMETER (HE-15-S)	SHUTTLE IMAGING MICROWAVE SYSTEM (EO-21-S)	AUTO LEVITATION (SP-13-S)	AUTO FURNACE/LEVITATION (SP-15-S)	DEDICATED SOLAR SORTIE MISSION (SO-01-S)	AMPS (AP-06-S)	SPACELAB 1 (NASA/ESA)	SPACELAB 2	LIFE SCIENCES LAB (LS-09-S)	SPACELAB 3
SORTIE PAYLOADS (CONT)																													
SP-03-S	SPA NO. 3 - LEVITATION (MANNED) (L+C)																					√				√			
SP-04-S	SPA NO. 4 - GENERAL PURPOSE (MANNED) (G+C)																					√				√			
SP-05-S	SPA NO. 5 - DEDICATED (MANNED) (B+F+L+G+C)																						√			√			
SP-12-S	SPA NO. 12 - AUTOMATED FURNACE (FP+CP)																					√							
SP-13-S	SPA NO. 13 - AUTOMATED LEVITATION (LP+CP)																					√							
SP-14-S	SPA NO. 14 - MANNED AND AUTOMATED (B+G+C+FP+LP)																						√			√			
SP-15-S	SPA NO. 15 - AUTOMATED FURNACE/LEVITATION (FP+LP+CP)																						√						
SP-16-S	SPA NO. 16 - BIOLOGICAL/GENERAL (MANNED) (B+G+C)																						√						
SP-19-S	SPA NO. 19 - BIOLOGICAL AND AUTOMATED (B+C+FP+LP)																						√			√			
SP-21-S	SPA NO. 21 - MINIMUM BIOLOGICAL (B+C)																					√				√			
SP-22-S	SPA NO. 22 - MINIMUM FURNACE (MANNED) (F+C)																					√				√			
SP-23-S	SPA NO. 23 - MINIMUM GENERAL (G+C)																					√				√			
SP-24-S	SPA NO. 24 - MINIMUM LEVITATION (MANNED) (L+C)																					√				√			
SP-31-S	BIOLOGICAL/FURNACE SUBELEMENTS AND CORE (SP-701/702)																									√			
LS-04-S	FREE FLYING TELEOPERATOR															√													
LS-09-S	LIFE SCIENCES SHUTTLE LABORATORY																											√	
LS-10-S	LIFE SCIENCES MINI-LABS																											√	
LS-13-S	LIFE SCIENCES FIRST US/ESRO SPACELAB MISSION (LS-701)																									√		√	
LS-14-S	ANIMAL WASTE MANAGEMENT SYSTEM DEMO. (LS-702)																											√	
ST-09-S	IRTCH																			√	√	√							
ST-13-S	WAKE SHIELD VACUUM FACILITY																					√			√	√			
ST-31-S	DROP DYNAMICS FACILITY (ST-703)																									√			
ST-32-S	WALL-LESS CHEMISTRY FACILITY (ST-704)																								√	√			
ST-33-S	THERMAL CONDUCTIVITY MEASUREMENTS																								√	√			
ST-34-S	CRITICAL POINT PHENOMENA																								√	√		√	
ST-35-S	COMBUSTION EXPERIMENTS																								√	√		√	
ST-37-S	TUNEABLE LASERS FOR ATMOSPHERIC MEASUREMENTS (ST-705) (EO-2)																								√	√			
ST-41-S	PYROTECHNIC/EXPLOSIVE TECHNOLOGY DEVELOPMENT (CS-5)																								√	√			
ST-43-S	AUTONOMOUS NAVIGATION, EARTH POINTING EXPT. (NV-2)																								√	√			
ST-44-S	MICROWAVE RADIOMETER (EO-4)																				√								
ST-45-S	METEOR SPECTROSCOPY (PH-6)																								√	√			
ST-46-S	ENVIRONMENTAL EFFECTS ON POLYMERIC MATERIALS (EN-3)																								√	√			
ST-47-S	ZERO-G STEAM GENERATOR (CS-2)																									√		√	
ST-49-S	MULTIPATH MEASUREMENTS (NV-3)																								√	√			
ST-51-S	MULTISPECTRAL SCANNER FOR COASTAL ZONE OCEANOGRAPHY (EO-3)																								√	√			
ST-52-S	SEARCH AND RESCUE IMAGING RADAR (EO-7/8)																								√	√			
ST-53-S	HADAMARD IMAGING SPECTROMETER (EO-13)																								√			√	
ST-54-S	COLONY GROWTH IN ZERO-G (MB-1)																									√		√	
ST-55-S	INTERPERSONAL TRANSFER OF MICRO-ORGANISMS IN ZERO-G (MB-2)																											√	
ST-56-S	SPECIAL PROPERTIES OF BILOGICAL CELLS (MB-5)																											√	
ST-57-S	SAMPLING OF AIRBORNE PARTICLES (EN-1) (ST-702)																											√	
ST-58-S	ADVANCED TECHNOLOGY LABORATORY P/L NO. I																								√	√			
ST-59-S	LIQUID HELIUM RESEARCH FACILITY																									√		√	
CN-04-S	ELECTROMAGNETIC ENVIRONMENT EXPT. (CN-701)																								√	√			
CN-05-S	CO2 LASER DATA RELAY LINK (CN-703)																								√	√			
CN-06-S	COMMUNICATION RELAY TESTS																								√	√			
CN-07-S	LARGE REFLECTOR DEPLOYMENT (CN-702)																								√		√		
CN-08-S	TWT OPEN ENVELOPE EXPERIMENTS (CN-704)																									√			
CN-09-S	MILLIMETER WAVE LARGE APERTURE ANTENNA EXPT.																									√			
CN-12-S	MICROWAVE INTERFEROMETER NAVIGATION AND TRACKING AID																									√			
CN-13-S	SHUTTLE NAVIGATION VIA GPS																								√	√			
CN-16-S	ADAPTIVE MULTIBEAM ANTENNA EXPT.																								√	√			
CN-18-S	VIDEO DATA COMPRESSION																								√	√			
CN-19-S	HIGH DATA RATE ND-YAG LASER TRANSMITTER																								√	√			
CN-20-S	ND-YAG LASER RECEIVER																										√		
CN-21-S	BANDWIDTH COMPRESSIVE MODULATION SHUTTLE EXPT.																								√	√			
CN-22-S	MICROWAVE MULTI-APPLICATIONS PAYLOAD																								√	√			
AUTOMATED PAYLOADS - WITHOUT IUS																													
AS-01-A	SPACE TELESCOPE					√																							
AS-01-R	SPACE TELESCOPE REVISIT					√																							
AS-23-A	MEDIUM APERTURE OPTICAL TELESCOPE					√																							
HE-01-A	LARGE X-RAY TELESCOPE FACILITY					√																							
HE-03-A	EXTENDED X-RAY SURVEY				√																								
HE-03-R	EXTENDED X-RAY SURVEY REVISIT				√																								
HE-05-A	HIGH LATITUDE COSMIC RAY SURVEY				√	√																							
HE-07-A	SMALL HIGH ENERGY SATELLITE	√																											
HE-08-A	LARGE HIGH ENERGY OBSERVATORY A (GAMMA RAY)	√																											
HE-09-A	LARGE HIGH ENERGY OBSERVATORY B (MAGNETIC SPECTROMETER)	√																											
HE-10-A	LARGE HIGH ENERGY OBSERVATORY C (NUCLEAR CALORIMETER)	√																											
HE-11-A	LARGE HIGH ENERGY OBSERVATORY D 1.2 m X-RAY TELESCOPE)	√																											
HE-11-R	LARGE HIGH ENERGY OBSERVATORY D REVISIT	√																											
HE-12-A	COSMIC RAY LABORATORY	√																											
HE-24-A	EXPLORER GAMMA RAY TELESCOPE (EGRET)	√																											
SO-02-A	LARGE SOLAR OBSERVATORY					√																							
SO-03-A	SOLAR MAXIMUM MISSION (SMM)	√																											
SO-06-A	FLARE COARSE MONITORING PAYLOAD	√																											
SO-08-A	SOLAR NEUTRON AND GAMMA RAY PAYLOAD	√																											
AP-04-A	GRAVITY AND RELATIVITY SATELLITE - LEO		√																										
EO-08-A	LANDSAT-D (EOS-D)				√																								
EO-10-A	APPLICATIONS EXPLORER				√																								
EO-12-A	TIROS-O				√																								
EO-61-A	EARTH RESOURCES SURVEY OPERATIONAL SATELLITE				√																								
OP-02-A	GRAVITY GRADIOMETER		√																										

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Table 2-3 Correlation of Candidate Payloads to Program Payloads (Continued)

SSPD PAYLOAD \ PSS STUDY REPRESENTATIVE P/L MODEL	SOLAR MAXIMUM MISSION (SMM) (SO-03-A)	GRAVITY 2 RELATIVITY SATELLITE (GRS) (AP-04-A)	BIOMEDICAL EXPERIMENT SCIENTIFIC SATELLITE (BESS) (LS-02-A)	EARTH OBSERVATORY SATELLITE (EOS) (EO-08-A)	SPACE TELESCOPE (AS-01-A)	STORMSAT (EO-15-A)	SPHINX (ST-02/03-A)	PIONEER JUPITER ORBITER PROBE	LONG DURATION EXPOSURE FACILITY (LDEF) (ST-01-A)	DISASTER WARNING SATELLITE (DWS) (CN-54-A)	FOREIGN SYNCHRONOUS METEOROLOGICAL SATELLITE (FSMS) (EO-57-A)	SPACE TEST PROJECT (STP)	INTERIM UPPER STAGE (IUS)	DOD/IUS-CLASSIFIED PAYLOAD	TELEOPERATOR ORBITER BAY EXPERIMENT (LS-04-S)	1M UV TELESCOPE (AS-04-S)	SHUTTLE IR TELESCOPE FACILITY (AS-01-S)	DEEP SKY UV TELESCOPE (AS-03-S)	MAGNETIC SPECTROMETER (HE-15-S)	SHUTTLE IMAGING MICROWAVE SYSTEM (EO-21-S)	AUTO LEVITATION (SP-13-S)	AUTO FURNACE/LEVITATION (SP-15-S)	DEDICATED SOLAR SORTIE MISSION (SO-01-S)	AMPS (AP-06-S)	SPACELAB 1 (NASA/ESA)	SPACELAB 2	LIFE SCIENCES LAB (LS-06-S)	SPACELAB 3
AUTOMATED PAYLOADS - WITHOUT IUS (CONCL)																												
OP-03-A MINI-LAGEOS		√																										
OP-04-A GRAVITY FIELD SATELLITE		√																										
OP-05-A VECTOR MAGNETOMETER SATELLITE		√																										
OP-07-A SEASAT-B		√																										
OP-51-A GLOBAL EARTH AND OCEAN MONITOR SYSTEM		√																										
LS-02-A BIOMEDICAL EXPERIMENT SCIENTIFIC SATELLITE			√																									
ST-01-A LONG DURATION EXPOSURE FACILITY									√																			
AUTOMATED PAYLOADS - WITH IUS																												
AS-02-A EXTRA CORONAL LYMAN ALPHA EXPLORER						√							√															
AS-05-A ADVANCED RADIO EXPLORER						√																						
AS-16-A LARGE RADIO OBSERVATORY ARRAY (LROA)						√																						
AS-16-R LARGE RADIO OBSERVATORY ARRAY REVISIT						√																						
SO-05-A SOLAR RADIO ASTRONOMY ARRAY						√																						
SO-07-A SOLAR WIND AND ENERGETIC PARTICLES						√																						
AP-01-A UPPER ATMOSPHERE EXPLORER						√																						
AP-02-A EXPLORER - MEDIUM ALTITUDE						√																						
AP-03-A EXPLORER - HIGH ALTITUDE						√																						
AP-05-A ENVIRONMENTAL PERTURBATION SATELLITE - A						√																						
AP-06-A GRAVITY AND RELATIVITY SATELLITE - SOLAR						√																						
AP-07-A ENVIRONMENTAL PERTURBATION SATELLITE - B						√																						
AP-08-A HELIOCENTRIC AND INTERSTELLAR SPACECRAFT						√																						
EO-09-A SYNCHRONOUS EARTH OBSERVATORY SATELLITE										√	√																	
EO-15-A STORM SATELLITE - B										√	√																	
EO-56-A OPERATIONAL ENVIRONMENTAL SATELLITE										√	√																	
EO-57-A FOREIGN SYNCHRONOUS METEOROLOGICAL SATELLITE											√																	
EO-58-A GEOSYNCHRONOUS OPERATIONAL ENVIRONMENTAL SATELLITE											√																	
EO-59-A GEOSYNCHRONOUS EARTH RESOURCES SATELLITE										√	√																	
EO-62-A FOREIGN SYNCHRONOUS EARTH OBSERVATORY SATELLITE										√	√																	
OP-01-A GEOPAUSE										√	√																	
OP-06-A MAGNETIC FIELD MONITOR SATELLITE										√	√																	
ST-02-A SPHINX-B							√																					
ST-03-A SPHINX-C							√																					
PL-01-A MARS SURFACE SAMPLE RETURN								√																				
PL-07-A VENUS ORBITAL IMAGING RADAR								√																				
PL-09-A MARINER MERCURY ORBITER								√																				
PL-12-A MARINER JUPITER ORBITER								√																				
PL-13-A PIONEER JUPITER ORBITER/PROBE								√																				
PL-14-A MARINER SATURN ORBITER								√																				
PL-15-A HALLEY COMET FLYBY								√																				
PL-20-A ASTEROID RENDEZVOUS								√																				
PL-21-A ENCKE BALLISTIC FLYBY								√																				
PL-22-A PIONEER SATURN/URANUS/TITAN PROBE								√																				
PL-28-A PIONEER MARS SURFACE PENETRATOR								√																				
PL-29-A MARINER MARS POLAR ORBITER								√																				
PL-31-A PIONEER JUPITER SWINGBY OUT-OF-ECLIPTIC								√																				
PL-32-A OUT-OF-ECLIPTIC SOLAR OBSERVATORY								√																				
PL-33-A TEMPLE-2 RENDEZVOUS								√																				
CN-51-A INTERNATIONAL TELECOMMUNICATIONS SATELLITE										√																		
CN-52-A US DOMSAT-A										√																		
CN-53-A US DOMSAT-B										√																		
CN-54-A DISASTER WARNING SATELLITE										√																		
CN-55-A TRAFFIC MANAGEMENT SATELLITE										√																		
CN-56-A FOREIGN COMMUNICATIONS SATELLITE-A										√																		
CN-58-A US TRACKING AND DATA RELAY SATELLITE-C										√																		
CN-59-A COMMUNICATIONS R&D/PROTOTYPE SATELLITE										√																		
CN-60-A FOREIGN COMMUNICATIONS SATELLITE-B										√																		
LU-01-A LUNAR ORBITER								√																				
LU-02-A LUNAR ROVER								√																				
LU-03-A LUNAR HALO SATELLITE								√																				
LU-04-A LUNAR SAMPLE RETURN								√					√															

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Table 2-4 Candidate Payloads Analyzed by Type - Sortie

PAYLOAD \ TYPE	SPACELAB MODULE	SPACELAB PALLET	BAY MOUNTED	PARTIAL CARGO	FULL CARGO	GROUND CONTROL	ON-ORBIT CONTROL	COMMENTS
1M UV TELESCOPE (SUOT) AS-04-S		X	X	X		X	X	
SHUTTLE INFRA-RED TELE-SCOPE FACILITY AS-01-A		X		X		X	X	
AMPS AP-06-S	X	X			X		X	
DEEP SKY UV TELESCOPE AS-03-S		X		X			X	
DEDICATED SOLAR SORTIE MISSION SO-01-S		X	X		X		X	
SPACELAB 1 NASA/ESA	X	X			X		X	MULTIPLE PAYLOADS, FIRST OPERATIONAL SHUTTLE FLIGHT
SPACELAB 2		X			X		X	
MAGNETIC SPECTROMETER HE-15-S			X	X			X	PRINCIPALLY CRT/ KEYBOARD/COMPUTER
SIMS A EO-21-S			X	X			X	SEMI-AUTOMATIC AFTER INITIAL STARTUP
AUTOMATED LEVITATION SP-13-S		X		X			X	
AUTOMATED FURNANCE/ LEVITATION SP-15-S		X		X			X	
LIFE SCIENCES LAB LS-09-S	X			X			X	
SPACELAB 3	X	X			X			

Table 2-5 Candidate Payloads Analyzed by Type - Free-Flyer

PAYLOAD \ TYPE	PARTIAL CARGO	FULL CARGO	WITH IUS	WITHOUT IUS	RETRIEVED	COMMENTS
SOLAR MAXIMUM MISSION SO-03-A	X			X	X	
GRAVITY & RELATIVITY SATELLITE AP-04-A	X			X	SOME	
BIOMEDICAL EXPERIMENT SCIENTIFIC SATELLITE LS-02-A	X			X	X	POSSIBLE EXP. MODULE EXCHANGE VIA TUNNEL/SPACELAB
EARTH OBSERVATORY SATELLITE EO-08-A	X		X	X	SOME	POSSIBLE SERVICING VIA GSFC FLIGHT SUPPORT SYSTEM
SPACE TELESCOPE AS-01-A		X		X	X	IFM POSSIBLE IN ORBITER BAY
STORMSAT EO-15-A	X		X			
SPHINX B/C ST-02/03-A	X		X			
PIONEER JUPITER ORBITER PROBE	X		X			
LONG DURATION EXPOSURE FACILITY ST-01-A	X			X	X	
DISASTER WARNING SATELLITE CN-54-A	X		X			
FOREIGN SYNCHRONOUS METEOROLOGICAL SATELLITE EO-57-A	X		X			
IUS	X		X			
SPACE TEST PROJECT SATELLITE (STP)	X		X			
EOTS/TOBE LS-04-S	X			X	X	FULL ON-ORBIT OPERATIONAL CONTROL
DOD CLASSIFIED		X	X			

2.3.2 Payload Matrices - The twenty-eight payloads were evaluated in detail utilizing the results presented above as to their controls and displays requirements and matrices were prepared for each payload. These matrices provided the selection rationale and exhibited the comprehensive and representative features of each payload. The matrices consisted of two types--Matrix I evaluated the payload C&D requirements by carrier and program/project, whereas the Matrix II evaluated the payload C&D requirements by type and engineering discipline by missions. These matrices were presented as a separate handout at the first Design Review held on January 22, 1976 at NASA/MSFC, Huntsville, Alabama.

Typical examples of the two matrices are presented on Tables 2-6 and 2-7. As noted on both these tables, the second column C&D requirements listed where applicable the quantified requirement values. These matrices were primarily utilized in developing the functional C&D requirements. The matrices were presented as separate handouts at the first Design Review, and therefore are not enclosed as part of this final report.

2.4 Paylaod Missions - The study ground rule agreed on with NASA/MSFC was to analyze in this study the missions starting with the early Spacelab 2 (1980) and those subsequent missions through 1990.

The various NASA Mission Models (572 Yardley Model, October 1973 Traffic Model, etc) were utilized in evaluating the missions presently planned as scheduled missions during this time period (1980 through 1990). The number of missions presently scheduled during this time period is approximately 360. As in the case of the final payload selections, a similar technique was utilized to reduce the total number of missions to an amount which could be effectively evaluated during this study.

The 360 missions were reviewed and evaluated in combination with the twenty-eight payload candidates selected. This systematic approach enabled the quantity of missions selected as candidates for this study to number eighteen and these are listed on Table 2-8. These missions bound and are representative of the control and display requirements of the remaining 342

Table 2-6 Example of Matrix 1 - Payload C&D Requirements by Carrier and Program/Project

PAYLOAD	POTENTIAL C&D REQM'TS	STS SYSTEM/CARRIER AFFECTED: ORB BAY	AFD	MID-DECK	MODULE	IUS	OTHER	PAYLOAD PROGRAM OR PROJECT: SEP. PROJ.	PROGRAM	NASA CENTER	OTHER
EOS EO-08-A	1. ORBITER PTG-DEPLOYMENT ACCURACY-1800 $\widehat{SEC}$ FOR 0.5 HR STABILITY-1800 $\widehat{SEC}$ FOR 0.5 HR STABILITY RATE: 180 $\widehat{SEC}$/SEC		X						EOS/SMM/LHEO/ EXPL	GSFC	LCMS CLASS, MR. CEPOLLINA
	2. PROPULSION ORBIT ADJUST SUBSYSTEM - N_2H_4 PROPELLANT/TANKS - GN_2 PROP. FEED/TANKS -THRUSTERS (4) -ISOLATION VALVES -THRUSTER VALVES		X								
	4. 406 WATT AVG DC POWER/ORBITER	X	X								
	5. CCTV TO INSPECT P/L DURING DEPLOYMENT/ RETRIEVAL	X	X								

Table 2-7 Example of Matrix II - Payload C&D Requirements by Type and Engineering Discipline - By Mission

PAYLOAD	POTENTIAL C&D REQM'TS	TYPE REQUIREMENT: PHYSICAL	TYPE REQUIREMENT: FUNCTIONAL	TYPE REQUIREMENT: OPERATIONAL	DISCIPLINE IMPACTED: STRUC MECH	THERMAL	ELEC	DATA MGMT	COMM	NAV/PTG	C&W	SOFTWARE	VISUAL	CONTROL ELECTRONICS	MISSION
GRAVITY & RELATIVITY SATELLITE	1. ORBITER PTG-DEPLOY ACCURACY: 1800 SEC FOR 0.5 HR STABILITY: 1800 SEC FOR 0.5 HR STABILITY RATE: 18 SEC/SEC	ORBITER SYSTEMS	REQUEST ORBITER PTG	ORBITER MAINTAIN POSITION						X					1982 BESS/ GRS DEPLOY, SMM RETRIEVE
	4. 1100 WATTS AVG (13.5 HRS)/ ORBITER	SWITCHING CONTROL	MONITOR STATUS	ORBITER POWER			X								
	6. CRT FOR CHECKOUT AND MONITORING	CRT DISPLAY	SELECT PARAMETER FOR DIS-PLAY									X	X		

missions and are classified into the following group types: eight free-flyers, four pallet mounted, two hybrid, and four Spacelab missions. The free-flyer missions, as noted on Table 2-8, consist both of payloads utilizing the Interim Upper Stage (IUS) for inserting payloads from the low earth orbit to a higher or synchronous orbit, and those multiple payload missions [Biomedical Experiment Scientific Satellite (BESS), Gravity and Relativity Satellite (GRS), Solar Maximum Mission (SMM)] which utilize the multi-mission spacecraft.

Table 2-8 Payload Missions

FREE-FLYERS	PALLET MOUNTED
• Jupiter Orbiter Probe-IUS	• Astronomy Facility
• BESS/GRS/SMM	• Dedicated Solar Sortie Mission
• STORMSAT/SPHINX-IUS	• SIRTF and Deep Sky UV Survey Telescope
• LANDSAT (EOS)	• Spacelab 2
• Space Telescope/BESS	
• DWS/FSMS-IUS	HYBRID (PALLET + AUTOMATED)
• DOD/STP-IUS	
• DOD/IUS - Classified Payload	• LDEF/Auto Levitation
	• BESS/Auto Levitation/Furnace/DWS
SPACELAB (Pressure Module + Pallet)	
• Spacelab 1	
• Spacelab 3	
• AMPS	
• Life Sciences Laboratory	

The twenty-eight payloads and the eighteen mission listings were presented at the first Design Review held on January 22, 1976, and at this time the Steering Group approved the payload list with minor changes; i.e., the addition of a classified DOD payload and Spacelab were accepted as listed.

3.0 FUNCTIONAL ANALYSIS

3.1 Payloads Functional Controls and Displays Requirements - The controls and displays (C&D) requirements matrices for each of the study payloads (listed in Section 2.0) were utilized to develop the functional controls and displays requirements for each of the 28 payloads. Supplemental payload data were also obtained through telecon contacts with the Principal investigators and payload project personnel for those payloads that were relatively undefined or lacked detailed descriptions; e.g., LDEF, SPHINX, SIRTF, SIMS, etc.

The contacts made with the payload user community provided their desires as to the crew activities related to C&D to be performed on-orbit at the AFD. This information was very beneficial in establishing the functional C&D requirements.

The functional C&D requirements developed were presented as a separate handout at the Second Design Review held on March 16, 1976 at Martin Marietta Corporation in Denver, Colorado. An example of the matrix format utilized is illustrated in Figure 3-1 for the Earth Observation Satellite payload.

3.2 Functional Analysis Diagrams - Functional analysis diagrams were developed for the study payloads. These diagrams presented the payload's functional activities flow based on the six mission phases established. These phases are:

- 1 - launch, ascent, orbit insertion;
- 2 - on-orbit checkout and activation;
- 3 - on-orbit operation;
- 4 - deployment/retrieval;
- 5 - on-orbit deactivation;
- 6 - descent, landing, post-landing.

The diagrams were useful in illustrating the activities performed during each of the mission phases specified. An example of a typical functional diagram prepared for the SIRTF payload is presented in Figure 3-2. To acquire detailed functional C&D requirements for any of the mission phase activities required a

PAYLOAD SUBSYSTEMS AND ELEMENT CATEGORIES ①	FUNCTIONAL C&D REQUIREMENTS	MISSION PHASE ②	STA. LOCATION ③	TIME DURATION (min) ④	REMARKS
	CONTROLS				
1. Orbiter primary supply to Spacelab igloo. Unregulated 25-32V DC	1a) Control to enable Orbiter power to Spacelab bus.	2, 5	PS	2	1a) Hardwire to switch on PSS to permit fast shutdown in event of short indication.
2. Spacelab power to SIRTF major elements	2a) Control to enable Spacelab bus power to activate IPS	2, 5			
a) IPS	2b) Control to enable Spacelab bus power to activate telescope and equipment	2, 5			
b) Telescope and associated equipment	3a) &b) Control to place individual LH_2 and LO_2 containers on line and to isolate depleted containers	2, 3			3a) b) Additional LH_2 and LO_2 will be required for SIRTF missions longer than 7 days.
0.1 Kw nonoperating 5.0 Kw operating	3c) Control to allow H_2O collection in onboard tanks and to dump H_2O at appropriate times		PS	2	
	DISPLAYS				
	1a) Display power supply to igloo - ON/OFF	2, 5	PS	-	
	a) Display power supply voltage - 25-32V DC	2, 5			
	a) Display power supply current - 200 Amp (max)	2			
	2a) Display IPS power - ON/OFF	2			
	a) Display IPS volts	2			
	a) Display IPS current	2			

NOTES: ① Categories--Propulsion; Environmental Control; Electrical Power; Structures; Guidance, Navigation and Control; Attitude Control; Communications and Data Management; and Specialized Sensors/Scientific Instruments

② 1 - Launch, Ascent, Orbit Insertion
2 - On-Orbit Checkout/Activation
3 - On-Orbit Operation
4 - Deployment/Retrieval
5 - On-Orbit Deactivation
6 - Descent, Landing, Post-Landing

③ Station C&D Function is Performed
- Payload Station (PS)
- Mission Station (MS)
- On-Orbit Station (OOS)

④ Time required to perform activity

Figure 3-1 Functional C&D Requirements for Related Payload Flight Phases (Earth Observation Satellite)

cradle mechanism. The SPHINX payload utilizes the IUS for insertion into orbit and this payload was also deployed by the RMS.

4) LANDSAT - EOS - The Earth Observation Satellite, being a single free-flyer payload for this mission, employs the MMS configuration. Since it is a single payload, the flight support system utilized included: retention cradle mechanism; positioning platform; and the docking mechanism.

5) Space Telescope/BESS - This mission consists of deployment of the Space Telescope (ST) utilizing the Payload Installation and Deployment Assembly (PIDA) and the retrieval of BESS via the docking mechanism, positioning platform and retention cradle of the FSS.

6) DWS/FSMS - IUS - Both of these payloads are free-flyers and on this mission both are deployed. The Disaster Warning Satellite (DWS) is presently identified as one of the payloads that will utilize the Multi-use Modular Spacecraft (MMS) design. For our functional C&D requirements analysis the MMS was considered, as well as the retention cradle of the FSS for latching/unlatching the payload in the payload cargo bay area. The Orbiter remote manipulator system (RMS) was utilized to deploy DWS.

The Foreign Synchronous Meteorological Satellite (FSMS) utilizes the IUS to insert the payload into a synchronous orbit. For our analysis the retention cradle was considered and the FSMS-IUS combination deployment activity was accomplished via the remote manipulator system (RMS).

7) DOD/STP - IUS and DOD/Classified Payload - IUS - Both of these missions employ the IUS for orbit insertion and deployment is accomplished by use of the RMS. Experiments for the STP payload are still undefined and the example for the classified payload could be considered as typical.

3.3.2 Hybrid Missions

1) LDEF/Auto Levitation - The Long Duration Exposure Facility is retrieved via usage of PIDA. The specific experiment candidates for this payload are still undefined. The Auto Levitation payload is mounted on a spacelab pallet and the functional C&D requirements are minimal. The majority of the on-orbit operations are automated and require activation only.

2) <u>BESS/Auto Levitation/Furnace/DWS</u> - This mission consists of the deployment of BESS and the retrieval of DWS. The auto levitation/furnace payload is pallet mounted.

For the deployment of BESS, a modified flight support system as proposed by NASA/GSFC was utilized. This system included: (1) retention cradle mechanism; (2) positioning platform; and (3) docking module. The retrieval of the Disaster Warning Satellite (DWS) was accomplished with the PIDA.

3.3.3 <u>Pallet Mounted Payloads</u> - The four pallet mounted payloads are listed on Table 2-8, and the principal features of each are presented herein.

1) <u>Astronomy Facility Mission</u> - The experiments and instruments that make up the Astronomy Facility are listed on Table 3-1. The mission as analyzed is the one proposed by the astronomy definition team under Karl Henize, Team Leader, NASA/JSC-TE.

Table 3-1 Astronomy Facility Mission

<u>SUOT FACILITY</u>	
• SPACELAB UV-OPTICAL TELESCOPE (SUOT)	
• FINDER TELESCOPE	
• ACQUISITION CAMERA	
<u>FOCAL PLANE INSTRUMENTS</u>	
• DIRECT IMAGING CAMERA - (ON ALL MISSIONS)	
• FAR UV SPECTROGRAPH	Two Selected for Any Mission
• PRECISELY CALIBRATED SPECTROPHOTOMETER	
• PLANETARY IMAGING CAMERA	
<u>ADDITIONAL SMALL PAYLOADS</u>	
• UV PHOTOMETER (2)	• MICROCHANNEL SPECTROMETER
• IMAGING TELESCOPE	• IR TELESCOPE
• IUE SPECTROGRAPH	• SCHWARZCHILD CAMERA
• UV POLARIMETER	• SCHMIDT CAMERAS (2)
• EUV SPECTROMETER	

To understand the complexity of this mission can be effectively accomplished by referring to Figure 3-3 which illustrates the arrangement of the instruments on the Spacelab pallets. As noted, the SUOT baseline telescope utilizes two pallets and the remaining instruments are arranged as shown on the remaining three pallets. The basic SUOT telescope and its focal plane instruments utilize the Spacelab Instrument Pointing System (IPS) for target acquisition. The remaining 11 small payloads utilize a Small Instrument Pointing System (SIPS) on each of the three remaining pallets.

2) Dedicated Solar Sortie Mission - The Dedicated Solar Sortie Mission (DSSM) includes the 12 experiments identified on Table 3-2. The initial six experiments are anticipated to be modified Skylab ATM experiments.

Table 3-2 Dedicated Solar Sortie Mission

EXPERIMENTS
• X-RAY TELESCOPE
• WHITE LIGHT CORONAGRAPH
• UV SPECTROMETER
• X-RAY SPECTROGRAPH
• UV X MONITOR
• UV X SPECTROHELIOGRAPH
• EUV SPECTROHELIOGRAPH
• HARD X-RAY COLLIMATOR
• 65CM PHOTOHELIOGRAPH
• GAMMA-RAY SPECTROMETER
• X-RAY BURST DETECTOR
• He I LINE PROFILE

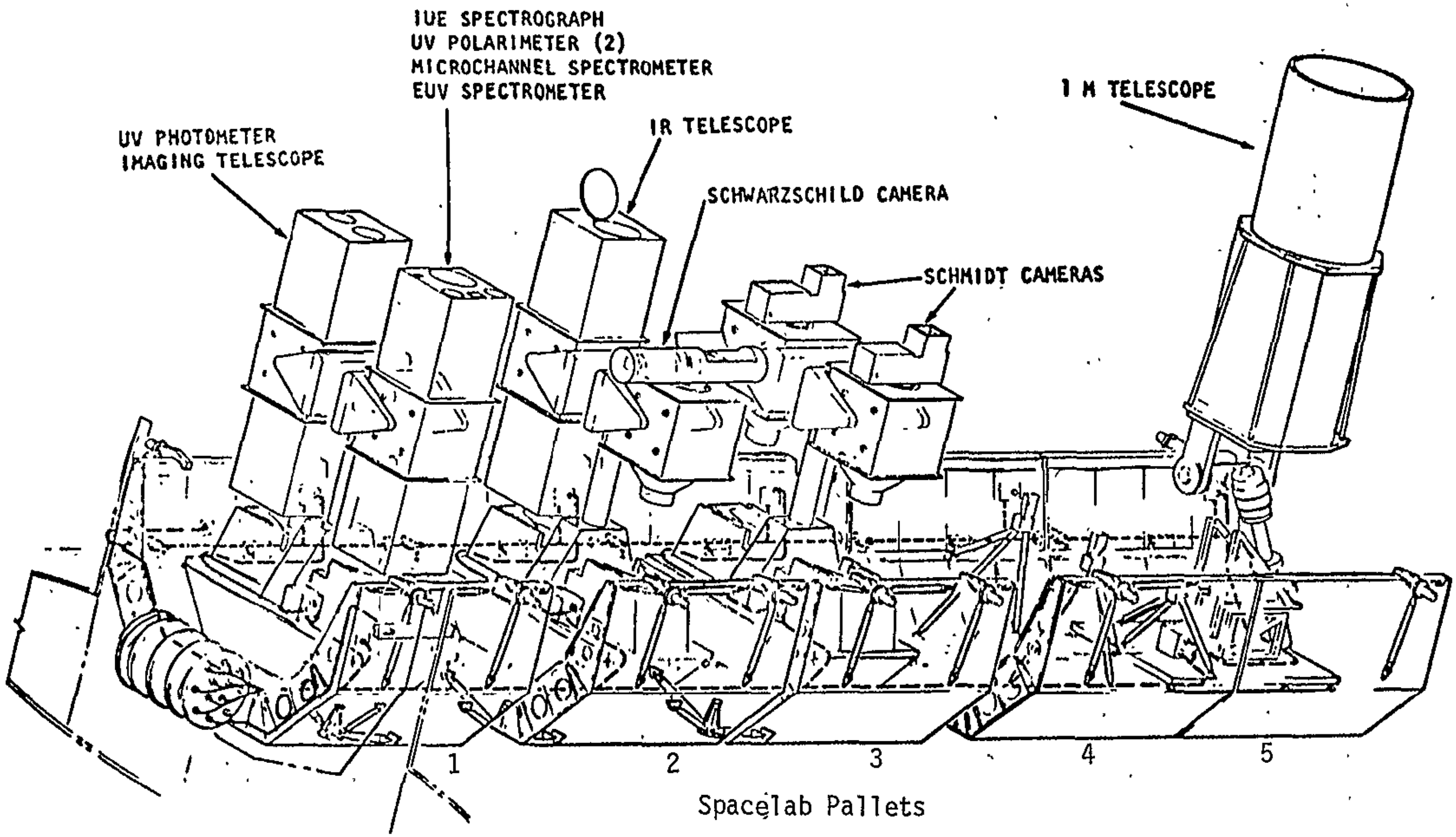

Figure 3-3 Astronomy Facility Mission Configured on Pallets

The arrangement of the experiments on the five Spacelab pallets is presented on Figure 3-4. Pallets 1 through 3 include individual SIPS for pointing the nine experiments, whereas pallet 4 utilizes a modified SIPS for the 65cm Helioscope. The remaining two experiments, Gamma-ray Spectrometer and X-ray Burst Detector, are hard mounted on pallet 5.

3) Spacelab IR Telescope Facility and Deep Sky UV Survey Telescope - The Spacelab IR Telescope Facility (SIRTF) is a one meter cryogenically cooled telescope and requires two Spacelab pallets in the stowed position. Pointing of the instrument will be accomplished with an IPS. The Deep Sky UV Survey Telescope (DUST) presently is a 0.75 meter folded reflective Schmidt Telescope for maximum coverage of the desired celestial area in the earth's umbra. This instrument will require two Spacelab pallets in the stowed position and it will acquire its target areas with an IPS.

4) Spacelab 2 - The Spacelab 2 strawman mission analyzed consisted of the 10 instruments listed on Table 3-3. As evident, the majority of the instruments considered are primarily solar, astronomy, or high energy equipment proposed for payloads previously analyzed. The experiment pointing mounts considered for these instruments are the IPS and miniaturized pointing mount.

Table 3-3 Spacelab 2 Mission

INSTRUMENTS
• 65CM PHOTOHELIOGRAPH
• SOLAR MONITOR PACKAGE (MODIFIED H-ALPHA)
• X-RAY TELESCOPE
• LYMAN-ALPHA WHITE LIGHT CORONOGRAPH
• FAR UV SCHMIDT/SPECTROGRAPH
• EUV IMAGING TELESCOPE
• LOW LIGHT LEVEL TV
• COSMIC X-RAY TELESCOPE, SKYLARK
• TRANSITION RADIATION SPECTROMETER
• HIGH SENSITIVITY X-RAY BURST

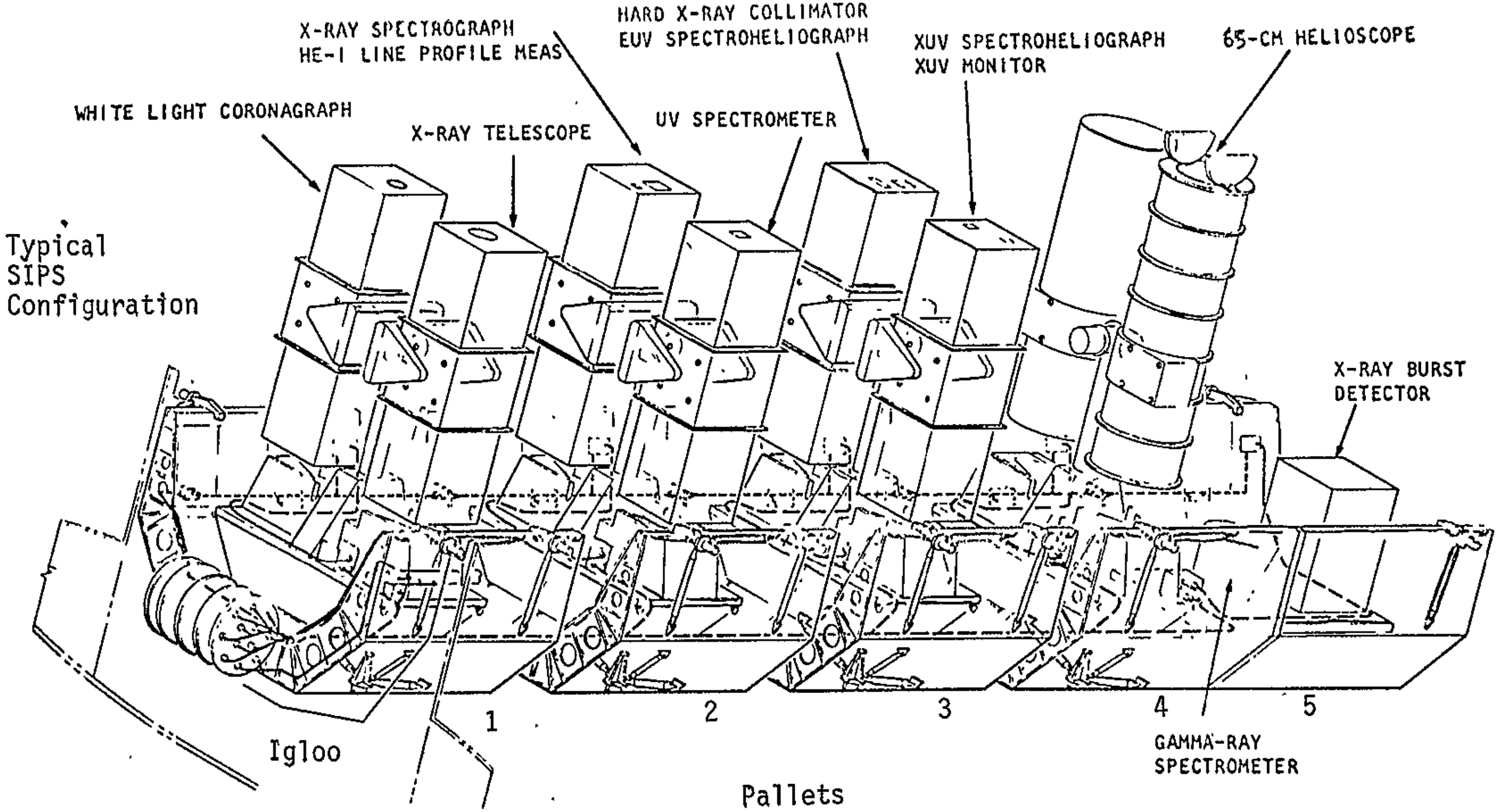

Figure 3-4 Dedicated Sola[illegible]tie Mission Configured on Pallets

3.3.4 Spacelab Pressurized Module Missions - The Spacelab missions investigated under this study were the four listed below:

- Spacelab 1
- Spacelab 3
- AMPS
- Life Science Laboratory

The above four payloads utilize the Spacelab pressurized module and the functional control and display requirements at the Aft Flight Deck are minimal, relating primarily to Spacelab activation; thus, this study task concentrated on the payloads identified in Section 2.0.

3.4 Detailed Functional Analysis - The detailed functional analysis results were presented in a separate handout, "Functional Analysis" at the Concept Review held on June 24, 1976 at NASA/MSFC. These results enabled the control and display requirements to be grouped either as "common" or "unique".

3.4.1 "Common" Functional C&D Requirements - The definition of "common" functional controls are those commands requiring typically two or three position discretes, adjustments, multiselections, or keyboard functions. "Common" displays are typically status indicators, lights and/or flags, digital, and cathode ray tube monitors. These are typical requirements for the majority of the STS program payloads.

The manual pointing controller for this study is considered as a "common" control function requirement due primarily to the many instruments that require fine pointing to acquire targets.

Examples of "common" control and display functional requirements are presented in Figure 3-5.

3.4.2 "Unique" Control and Display Functional Requirements - "Unique" C&D functional requirements as interpreted in this study are considered as specific requirements applicable to a single payload instrument or possibly to only a few of the instruments.

FUNCTIONAL REQUIREMENTS		PAYLOAD SUBSYSTEM	MISSION PHASE	REMARKS
CONTROL	DISPLAY			
		<u>SIS</u>		EXPERIMENT: X-Ray Telescope
• Activate High Voltage - (On/Off)	• High Voltage - (On/Off)	• Experiment Power	2, 3, 5	•
• Activate Power - (On/Off)	• Power - (On/Off)	• Camera	2, 3, 5	•
• Activate Thermal Power (Pri/Off/Sec)	• Power - (Pri/Off/Sec) • Thermal Sensor Data	• Thermal • Thermal	2, 3, 5 2, 3	• •
• Activate Cover - (Open/Close)	• Cover - (Open/Close)	• X-Ray Telescope Cover	2, 3, 5	• "<u>Common</u>"
• Select Filter - (1/2/3)	• Filter Selected (1/2/3)	• X-Ray Telescope Filter	2, 3	•
• Select Exposure - (Short/Norm/Long)	• Exposure Selected - (Short/Norm/Long)	• Camera	2, 3	•
• Adjust Brightness	• CRT (<u>Unique</u>)	• X-Ray Image	2, 3	▲ "<u>Unique</u>" X-Ray Image
• Adjust Focus	• CRT (<u>Unique</u>)	• X-Ray Image	2, 3	▲ "<u>Unique</u>" X-Ray Image
	• X-Ray Counts	• X-Ray Image Detector	3	• Detected during one sec
• Activate Alarm - (On/Off)	• Audio Alarm	• Flare Detector	3	
	• High Voltage Supply Failure	• Exp. Power	2, 3	▲ <u>Alert</u> (SM)
	• Aperture Control Failure	• Aperture Control	2, 3	▲ <u>Alert</u> (SM)
	• Be Detector Failure	• Exp. Detector	2, 3	
	• Al Detector Failure	• Exp. Detector	2, 3	▲ <u>Alert</u> (SM)

Figure 3-5 Functional C&D Requirements - Dedicated Solar Sortie Mission (DSSM)

Our investigation of the payloads presently planned for the STS program revealed that a number of payloads had many desires requested but for successful mission objectives these could be relinquished. The only "unique" requirements encountered were the ones presented in Figure 3-5 for the X-ray Telescope, which requires a CRT with a special phosphorous coating to display the X-ray image. (This is similar to the X-ray 3-in. monitor used on the Skylab ATM.) The other unique requirement was for the electron accelerator instrument on AMPS, which required an oscilloscope. However, AMPS presently utilizes the Spacelab pressurized module and no AFD C&D requirement exists.

The results of the mission functional C&D requirements as presented at the Concept Review are summarized on Table 3-4.

3.4.3 Time Functional Analysis - Mission timelining was performed for the Hybrid mission, BESS/Auto Levitation/Furnace/DWS. Figure 3-6 presents this data. (Decision was made early in the study and agreed upon to forego the timelines for the remaining missions and once the driver missions are selected then a power timeline analysis could be conducted for the most demanding mission.)

3.4.4 Driver Missions - The terminology used for "Driver" missions were those missions that required the maximum number of functional controls and displays requirements, and also would bound any mission combinations presently planned or that could be proposed in the future. The "Driver" missions selected are:

- Dedicated Solar Sortie Mission (DSSM)
- Astronomy Facility
- BESS/GRS/SMM
- BESS/Auto Levitation/Furnace/DWS

Also included, primarily because of its early mission status, was the Spacelab 2 mission.

Table 3-4 Summary of Mission Functional C&D Requirement Results

MISSION	FUNCTIONAL REQUIREMENTS	
	CONTROLS	DISPLAYS
A. FREE-FLYER		
• Jupiter Orbiter Probe - IUS	30	35
• DOD/STP - IUS	70	121
• DOD/Classified Payload - IUS	87	88
• STORMSAT/SPHINX - IUS	119	174
• DWS/FSMS - IUS	148	165
• LANDSAT (EOS)	124	181
• Space Telescope/BESS	144	189
• BESS/GRS/SMM	255	363
B. HYBRID		
• LDEF/Auto Lev/Furnace	78	101
• BESS/Auto Lev/Furnace/DWS	203	246
C. PALLET MOUNTED		
• SIRTF and Deep Sky UV Survey Telescope	107	179
• Spacelab 2	121	204
• Dedicated Solar Sortie	206	244
• Astronomy Facility	468	633

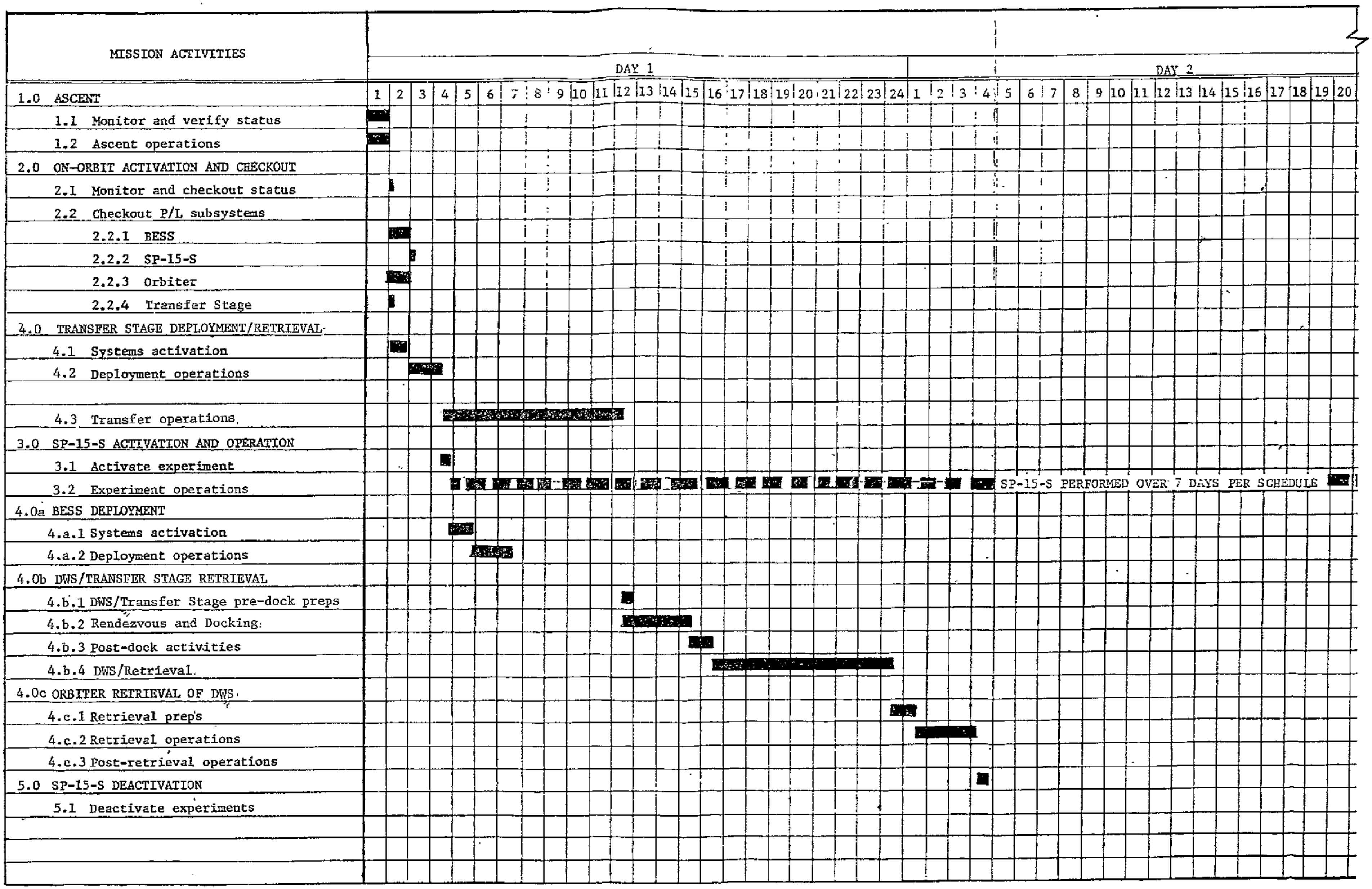

Figure 3-6 Mission Timeline - BESS Deployment, Auto Levitation/Furnace, DWS Retrieval

FOLDOUT FRAME 1

FOLDOUT FRAME 2

4.0 SYSTEM SYNTHESIS (TASK III)

In Task III of the study, the equipment options which could satisfy the C&D requirements identified in Task II were defined. The widest possible variety of available hardware and software, as individual pieces of equipment and as systems, was investigated. The intent was to synthesize a complete AFD system or systems which could accommodate the range of requirements identified for the study missions. The candidate equipment was defined in terms of technical characteristics, cost, and scheduling (DDT&E flows) requirements. Actual trade studies against selection criteria were performed as part of Task IV.

The investigations of payloads control and display requirements conducted in Tasks I and II revealed specific requirements which could in many cases be satisfied by any of several components or techniques. In Task III, each potential option was identified as an individual unit and, in the course of the task, as part of a synthesized system which comprised a potential AFD concept.

The types of components surveyed are listed in Table 4-1.

Table 4-1 Candidate Components Surveyed

• Switches	• Plasma displays	• Miniature CRTs
• Gages	• Memories	• Incandescent displays
• Keyboards	• Alphanumeric generators	• Fiber optic displays
• LED readouts	• Software languages	• Circuit breakers
• Hard copiers	• Man/Machine interface languages	• Potentiometers
• Computers	• Tape recorders and disks	• Analog meters
• Cathode ray tubes	• Central processors	
• Panel indicators	• Liquid crystal displays	
• Control handles	• Gas discharge flat packs	

It is important to note that Space Transportation System (STS) qualified hardware already exists in many of the categories listed, and are directly applicable for use in the AFD. Such components provide substantial advantages in procurement, spares requirements, maintenance/servicing, qualification costs and schedule risks. During the course of Task III, the identification of STS qualified

components provided the basis for formulation of complete AFD concepts. Table 4-2 lists the major components utilized by the Orbiter which are also required by the AFD C&D.

Table 4-2 STS-Qualified Components Applicable to AFD C&D

COMPONENT
Annunciators
Rotary Switches
Variable Transformer, Displays and Controls
Mission and Event Timers
Digital Select Thumbwheel Switch, Toggle Switches
Tape Meter
Mass Memory/Multifunction CRT Displays
Pushbutton Switches
Caution and Warning Electronics
Transformer (Power Displays and Controls)
Event Indicator, Electrical Indicator Meter

Tables 4-3, 4-4 and 4-5 show examples of the format utilized to define and compare equipment candidates. Technical and economic factors were summarized for each candidate in the specified application. In this way, major differences in terms of technical capabilities or cost could be identified. A similar matrix was generated for each component type.

Another important factor in determining potential system configurations was the availability of specific components on the required dates. Overall DDT&E (design, development, test and engineering) flows were generated so that schedule risk and required component lead times could be identified. These DDT&E flows

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Table 4-3 Component Data Sheet Example - Mechanical Switches

Candidate Types/Vendor — Comparative Factors	Toggle Switches — Vendor: McGraw Edison	Toggle Switches — Vendor: Texas Instr.	Toggle Switches — Vendor: Applied Resources	Rotary Switch: McGraw Edison	Rotary Switch: Applied Resources
Physical Parameters	(Values shown typ for 2-pole, 2 or 3 position)			(Values shown typ for single deck)	
Size (HxWxD) inches	1.40 x 1.00 x 1.45	1.40 x 1.00 x 1.45	1.40 x 0.75 x 1.45	1.8 dia x 3.1 (LEM,ATM) 1.27 dia x 2.25 (ERRP)	1.3 dia x 2.5 (leng. incl. conn.)
Weight (oz)	3.2 oz	3 oz	2.8 oz	6 oz	6.5 oz
Power	-Negl-	-Negl-	-Negl-	-Negl-	-Negl-
Variations Available	1 to 4 Pole; 2 or 3 position; momentary, maintained or locking			2 to 12 positions per deck (30°); shorting or nonshorting; 1 to 4 poles; multiple decks	
Performance Parameters Accuracy, Capacity Sensitivity, etc.	10 Amp Resistive @ 28 VDC	10 Amp Resistive @ 28 VDC	2 Amp Resistive @ 28 VDC	2.0 Amps ckt rating	2 Amp circuit rating, resistive @ 28 VDC
Development Status Previous/Proposed Use	RI use on Orbiter	LEM, CM, ATM, ERRP	Designed to meet Orbiter environments	LEM, ATM, ERRP	RI use on Orbiter
Cost Relative Cost/Unit delivered ($ 1976)	$400-700 depending on configuration	$400-700 depending on configuration	TBD	$800	$700 per unit average, regardless of configuration
Schedule Approximate lead time	20 weeks on present production run; 30 weeks on new run	12 weeks on 2-LS series only	20 weeks (est.)	30 weeks typ	20 weeks (est.)
Integration Parameters Servicing, etc.	---	---	---	---	---
Comments	---	All TI 2-LS series are DPDT. A SPDT configuration is available using an external jumper. Other military switches also available, but not flight-qualified.	Uses 2-sided PC cards and wiper arrangement of same construction as their rotary & thumbwheel switches. Additional poles do not increase size of this unit.	Standard is 12-position with 30° indexing. Also available in 36°, 60° indexing	(Same as McGraw Edison)

Table 4-4 Component Data Sheet Example - Panel Indicators

Candidate Types/ Vendor \ Comparative Factors	Status Indicator (Lamp)				
	Jay-El Products	Jay-El Products	Jay-El Products	Jay-El Products	Pen Keystone
Physical Parameters Size Weight Power Variations Available	P/N 10770 or 10771 0.925 x 0.925 x 3.25 3 oz (TBD watts) Stackable	P/N 10319 Flange Mt. 0.845 x 1.085 x 2.67 3 oz (TBD watts)	P/N 10620 0.75 x 0.75 x 1.97 2 oz (TBD watts) Stackable	P/N 10454 0.5 x 0.5 x 1.0 <1 oz (TBD watts)	Flange Mount 0.25 x 0.25 x 1.0 ≈0.5 oz 350 to 400 mw @ 5 VDC
Performance Parameters Accuracy, Capacity, Sensitivity, etc.	Special EE bulbs used	Special high intensity lamps		Special EE bulbs used	Uses single 60 ma EE type bulb. ≈15 f-L
Development Status Previous/Proposed Use	Same as Orbiter PB switch/indicator with switch components removed.	Same as Orbiter PB switch/indicator with switch components removed.	RI use on Orbiter in indicator only configuration.	RI use on Orbiter. Basic keyboard type as indicator only.	Used on LEM, ATM, EREP
Cost Relative cost/unit delivered ($ 1976)	$150 to 175 ea.	$200 to 250 ea.	$150 to 175 ea.	≈$25 ea.	(≈$150 ea. on Skylab)
Schedule Approx. lead time	≈12 weeks	≈12 weeks	≈12 weeks	≈12 weeks	(TBD) See Comments
Integration Parameters Servicing, etc.	Re-lampable from front of panel.			Re-lampable from front of panel.	Skylab units were not re-lampable, but could be designed for re-lamping
Comments	The depth of these units could be reduced by ≈1/4 to 1/3 if desirable from the switch/indicator to indicator only configuration.				Pen Keystone has essentially shut down its facility for space qualified panel indicators. Tooling, personnel, facilities, etc. have been retained.

Table 4-5 Component Data Sheet Example - Alphanumeric Displays

CANDIDATE TYPES/ VENDOR	CATHODE RAY TUBE DISPLAYS					DISTRIBUTED CATHODE DISPLAY	PLASMA DISPLAYS	
COMPARATIVE FACTORS	MOTOROLA	NORDEN	CONRAC	CONRAC	BENDIX	TEXAS INSTRUMENTS	HUGHES (BURROUGHS)	SAI TECHNOLOGY
Commercial Designation	Totalscope III					Digisplay	Self-Scan	Plasmascope, Model 2500
Military Designation	AN/UYK-29(V), and others	Display Unit, Orbiter	SMA 912 R	61001	CRT DI	(Preliminary Data)		AN/UTQ-10
Physical Parameters								
Screen size, (HxW)inches	10x12	5x7	2 ea. 5x7*	6.5x8.5	8.5x11	10x10	3.2x6.7	12x12(8.5x8.5 active)
Size (HxWxD), inches	24x17.5x19*	7.4x10.3x16	8.7x19x15	8x10x16.6	13x14x20	14x14x10*	TBD	13x13x11.5 or 14.5x19x11.5
Weight, pounds	130	25 (display only)	42 (display only)	35	50	80	TBD	68
Power, watts	650 (maximum)	130 (display only)	95 (display only)	132	50 (display only)	500	TBD (300 max)?	300 (max)
MTBF, hours	2,000 to 3,000	18,000	TBD	1,000	TBD	2,000	10,000	3,000+(?)(13 000 @ 25°C Hi Rel)
Max. voltage in system	18-20 Kv				TBD	6 Kv to 20 Kv	250V, DC	300 V
Equipment Complement								
Keyboard	Yes*	No	Not Furnished	Not Furnished	Yes	Yes	Yes	Yes
A/N Generator	Yes	Yes			Yes	Yes	Yes	Yes
Integral Memory & Logic	Yes	No			Yes	Yes	Yes	Yes
External Computer Compatibility	AN/UYK 7; 15; 20	Interface unit required			Interface options	Interface options	TBD	6 interface unit options
Edit Capability	Yes	No			Yes	Yes	Yes	Yes
Display Capabilities								
Brightness; foot lamberts	20	100(?)	30	120	100	70	50 (120)	50
Contrast; ambient, foot candles	10/1;30	25/1;100	TBD	TBD	8/1; 100	10/1	3/1 (with filter)	25/1
Video, refresh, scans/sec	Yes; 50	Yes; 55	Yes; 30	Yes; 30	Yes; 60	Yes; 60	Yes; 85	Yes; 3 (optionally higher)
Spot size, mils	12	12	10	10	10	12	30x40	10 to 12
Gray scale	Yes	Yes	Yes	Yes	Yes	Yes	Yes (better than CRT)	Optional - developmental
Alphanumerics; lines; characters	Yes, 80; 50	Yes	Yes	Yes	Yes	Yes	Yes	Yes; 32, 80
Graphics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Address Points	1024 - 4096	TBD	TBD	TBD	1,048,576	640,000	24,192	262,144
Cost, $	50 to 100K	TBD	TBD	TBD	TBD	50 to 100K	TBD	50 to 100K (on request)
Schedule - Lead Time	TBD	RI Spec.	TBD	TBD	Qual unit early '79 is tight	TBD	TBD	TBD
Development Status Qualification Tests	Current Military Prod. MIL-E-5400 MIL-E-16400	Intended for Space Shuttle usage	Industrial unit	Ruggedized Mil unit-not Shuttle qualified. MIL-E-5400, Class 1	Development to MIL-E-5400	Under development. Design to MIL-E-5400	Production (previous military and space usage, 4 programs) MIL E 5400	Developed - designed to MIL-E-5400, MIL-E-16400, MIL-STD-810B

are based on STS program requirements, and define when components must be available to meet overall program schedules. The groundrules and assumptions used to generate the DDT&E flows are listed in Table 4-6; and the DDT&E schedule summary is shown in Figure 4-1. Table 4-7 shows the component DDT&E requirements in terms of lead times prior to anticipated launch of Spacelab 2 (first mission wherein payload AFD C&D equipment is required).

The system synthesized as the output of Task III involved the general types of equipment listed in Table 4-8. This synthesis shows that certain types of control and display equipment were selected over others, based upon the technical, economic and programmatic factors described above. The selection of CRT displays instead of plasma displays, and STS-qualified event indicators instead of integrally lighted indicators, relates to those factors. Specific components (i.e., vendors, part numbers) and optimum component configurations were determined in Task IV (see Section 5.0).

Table 4-6 DDT&E Flows - Ground Rules and Assumptions

1. TERMINOLOGY:
   - Core C&D
   - Mission-Unique C&D
   - Components
   - Consoles
   - AFD System
   - Design Verification
   - Qualification
   - Flight
   - Protoflight
2. DESIGN VERIFICATION AND QUALIFICATION OF NEW COMPONENT DEVELOPMENT IS REQUIRED.
   - Core C&D Components
   - Mission-Unique C&D Components
3. DESIGN VERIFICATION TESTING OF THE AFD SYSTEM IS REQUIRED.
   - Core C&D
   - Each Mission-Unique C&D
4. THE CORE C&D DESIGN VERIFICATION TEST SETUP IS RETAINED AS PART OF A SIMULATOR FOR:
   - Design Verification Testing of Each Mission-Unique C&D
   - Acceptance Testing of the Core C&D Flight Hardware/Software
   - Acceptance Testing of Mission-Unique C&D Flight Hardware/Software
5. QUALIFICATION TESTING OF THE CONSOLES IS REQUIRED
   - Core C&D
   - Each Mission-Unique C&D

Table 4-6 (Concluded)

6. COMPATIBILITY OF THE MISSION-UNIQUE C&D FLIGHT HARDWARE/SOFTWARE WITH THE PAYLOAD, STS, AND CORE C&D IS VERIFIED AT KSC.

7. THREE (3) MONTHS ARE ALLOWED FOR KSC OPERATIONS.

8. INITIAL USAGE IS SPACELAB 2, OCTOBER 1980.

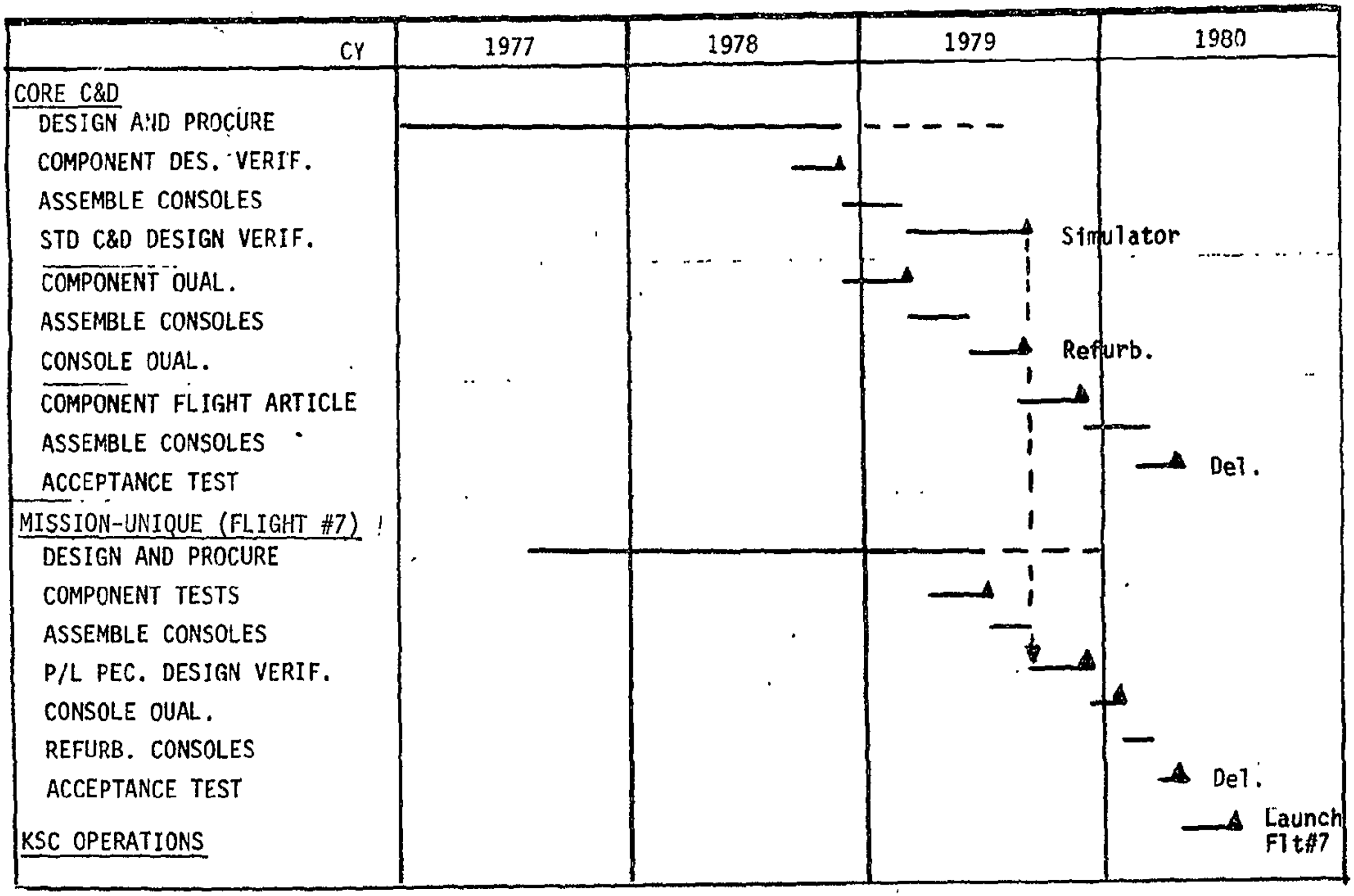

Figure 4-1 DDT&E Schedule Summary

Table 4-7 Component DDT&E Requirements

SUGGESTED COMPONENT START	TIME PRIOR TO LAUNCH (months)	COMPONENTS AVAILABLE FOR INTEGRATION	TIME PRIOR TO LAUNCH (months)
CORE C&D		CORE C&D	
• New Dev.	32 - 36	• Design Verif.	20 - 21
• New Buy	29 - 33	• Qualification	17 - 18
• Off-the-Shelf	26 - 30	• Flight	9 - 10
MISSION-UNIQUE C&D		MISSION-UNIQUE C&D	
• New Dev.	25 - 29	• Proto-Flight	13 - 14
• New Buy	22 - 26		
• Off-the-Shelf	19 - 23		

Table 4-8 AFD C&D System as Synthesized by Task III

COMPONENT DESCRIPTION	AFD UTILITY	POSSIBLE LOCATION
• CRT w/Alphanumeric Keyboard	• Experiment Activation, Experiment Operation, Data Display	• Payload Station - L10/L11 or Mission Station - R12
• CRT w/Video	• Experiment Pointing	• PS - L10/L11/A3 (CCTV)
• Manual Pointing Controller	• Experiment Pointing	• PS - L10/L11/Portable
• Multi-use Mission Support Equipment (MMSE) - Event Timers, Rotary Switches, Toggle Switches, Event Indicators (All STS qualified) Analog Meters, LED Displays, Potentiometers	• Payload Status, Operation	• PS or OOS - L10/L11/L12/ A6/A7
• Spacelab Tape Recorder	• Data Recording	• PS - L12

5.0 TRADE STUDIES (TASK IV)

In Task IV various trade studies were performed on the general AFD C&D system synthesized in Task III. The intent was to establish C&D interface compatibility with Orbiter AFD constraints, and Orbiter/Spacelab data management constraints, develop viable equipment and systems options to satisfy mission requirements, and define a complete AFD C&D concept for preliminary design and programmatic analysis in Tasks V and VI. To a large extent the trade studies conducted in Task IV were in the form of interface compatibility analysis; that is, the choice of a particular subsystem or operating method was in many cases determined by the compatibility of the particular subsystem with identified Orbiter or Spacelab systems. Four equipment configuration options were developed, all of which were feasible within known constraints, and these options were evaluated to determine an optimum system for preliminary design.

5.1 Constraints

5.1.1 Orbiter Physical Constraints - Orbiter interface constraints and resources which affect the design of the AFD C&D are--payload C&D panel areas, dedicated equipment volumes, equipment weight limitations, thermal dissipation, electrical power, available wiring in the AFD, and the video interface. These constraints apply to any proposed AFD C&D configuration and were considered in developing the various options.

Panel areas dedicated for C&D in the AFD consist of those shaded areas indicated in Figure 1-1. The R12 (at MS), L10, L11, and L12 (at PS) panel surfaces are 19-in. wide and 21-in. high. Panel surfaces available to payload C&D at the on-orbit station (panels A6 and A7) measure 19-in. wide by 14-in. high. All payload C&D (core and mission-unique) must fit within these panel areas.

Equipment volumes extend 20-in. below the panel surface at the PS and MS; the depth below the panels at the OOS is irregular and averages approximately 8-in. All C&D and associated electronics must be accommodated within these console dimensions. Additional limited volume dedicated to payload use is available

below the PS consoles, within geometry constraints dictated by Orbiter equipment also located there.

The weight of each console at the MS or PS is limited to 150 lbs; 15 lbs of this total is allocated to structure. The arrangement of bulky payload C&D equipment (e.g., CRTs, recorders) is impacted by this constraint.

Thermal dissipation and power dissipation are interrelated in that power utilization in the AFD is limited by the thermal cooling capacity of the Orbiter. The cooling capability provided in the AFD will be 475 lb/hr nominal flow of unfiltered cabin air in a temperature range of 65 to 90^{o}F and a dewpoint range of 45 to 62^{o}F. The total on-orbit cooling capability for the AFD (MS and PS) will be an average of 2560 Btu/hr (750 watts) in any three-hour period. The maximum allowable power dissipation in the same period is 1000 watts for 15 minutes. No active cooling is provided at the OOS.

Electrical power at the PS consists of 28V DC and 115V, 400 Hz AC. Power at the MS consists of 28V DC. A firm requirement also exists for 115V 400 Hz AC power at the MS (for the Spacelab CRT and Keyboard at R12). Orbiter 28V DC power is available at the OOS. Crossover wiring must be utilized to supply other than 28V DC power to the OOS, if required by a given C&D configuration.

The wiring available in the AFD is that provided for in the Orbiter system design. Specific types and numbers of wires are routed to and between the various AFD stations (PS, MS, OOS). Wiring available to payloads is summarized in Table 5-1. The Spacelab and CCD utilization of this capability is shown in Section 6.3.2.

5.1.2 Orbiter Command and Data Management Constraints - This section is limited to a discussion of the Orbiter equipment which is utilized at the AFD in support of payload mission operations. Emphasis will primarily be on the equipment which

Table 5-1 AFD Available Payload Wiring

WIRE TYPE	MSS - BULKHEAD	MSS - OOS	PSS - OOS	PSS - BULKHEAD	PSS - MSS
TSP	44	43	43	94	4
TP	30	15	15	88	0
COAX	0	0	4	3	3

TSP = Twisted Shielded Pair

TP = Twisted Pair

is utilized at the AFD in support of payload mission operations. Emphasis will primarily be on the equipment which interfaces with the C&D; however, other related Orbiter equipment will be briefly mentioned. Figure 5-1, the AFD Systems Interfaces, will be utilized as a reference for the equipment discussions in the remainder of this section.

5.1.2.1 Orbiter AFD Utilized Equipment - The Orbiter general purpose computer and input output processor (GPC/IOP) is the key to utilization of Orbiter equipment and services at the AFD. One of five Orbiter GPCs will be available for payload use during the on-orbit phase of flight. During other phases of flight the Orbiter GPC is not available for payload use. In addition, it should be noted that during the on-orbit phase only a portion of the assigned payload computer is available for use in that it will be shared with Orbiter system management tasks. During this operation if the Orbiter requires use of the computer as a result of other computer equipment failures, it has priority and can terminate the payload task. Within the above system constraints one Orbiter GPC/IOP is available for payload utilization provided it conforms to the standard Orbiter services in the systems software. These services are:

- Data acquisition;
- Data output handling;
- Fault detection and annunciation;
- Payload control supervisor;
- Uplink throughput;
- GN&C data transfer.

The data acquisition function is a service which places parameters from payload MDM and PCMMU into the computer data pool for use by mission-unique application software. The PCM master unit will process analog, discrete and digital words at a cyclic rate of one sample per second. The MDM channel also has the capability of processing analog, discrete, and serial digital data. Parameter of the above type which are acquired for fault detection or display shall be made available for downlink at a rate no greater than one sample per second. Data

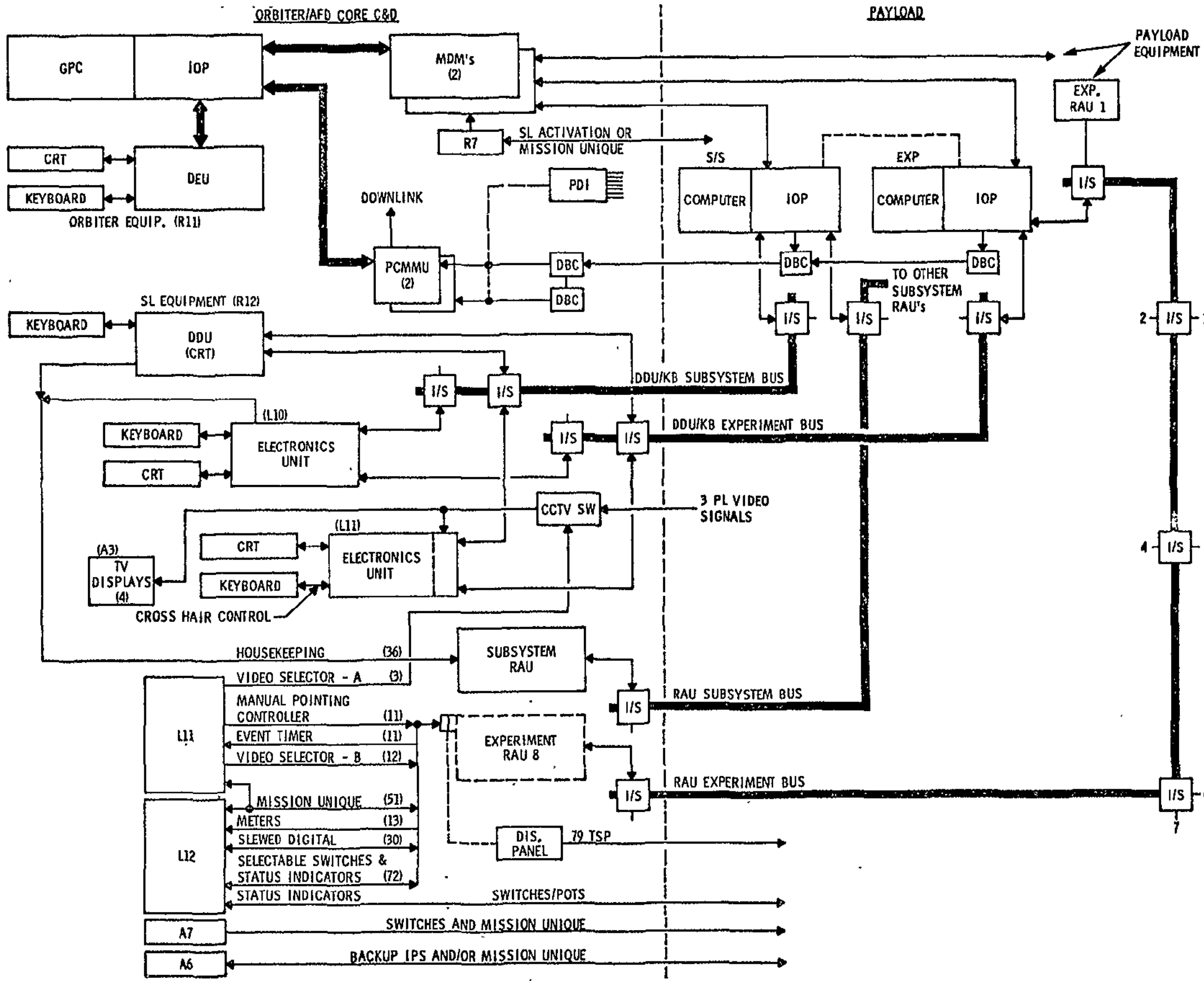

Figure 5-1 AFD C&D Systems Interface

acquisition for computation is constrained to 25 samples per second or integer submultiples thereof.

The data output handling function is a service which communicates with MDM outputs, displays and application software. The communication with the MDMs will handle analog, discrete, and serial digital data on a cyclic or on demand basis. The display output function shall have the capability to perform the functions necessary to output specified parameters, together with their status indicators to standard display pages. The output data pool will also communicate with mission-unique application software allowing interapplication software data transfers.

The fault detection and annunciation (FDA) function will have the capability to cyclically reference any payload data from the payload data pool. The FDA function will have the capability to perform fault detection on all specified data. This will include limit set selection, limit sensing, noise filtering, and reporting of standard error message to display unit.

The payload control supervisor (PCS) is an interpretive program which provides control of MDMs for either commanding or interrogation. Mission unique application software will provide the operators to be interpreted by the PCS. The operator codes available are:

1. BEGIN
2. END
3. ISSUE DISCRETE
4. WRITE POOL
5. READ POOL
6. READ DIRECT
7. SPARE
8. SPARE
9. DELAY
10. BRANCH
11. TEST

12. CALL
13. TEXT
14. STOP
15. RESUME
16. CANCEL

The uplink throughput function uplink commands via the Orbiter network signal processor (NSP) to the payload. The crew has the capability to exhibit or enable the UT function. When enabled the UT function allows transfer of uplink data via the serial MDM channel without crew action.

The GN&C data transfer function will provide the capability to transfer GNC initialization data to the payloads and receive experiment data from the payloads. The GNC data will be refreshed at a 6.25 Hz rate and contain state vector, attitude, attitude rate, and GMT time in time homogeneous data sets. The GNC data will also be made available for downlink and display. The payload will also have the capability to transfer data to the Orbiter GPC for experiment support via the serial MDMs channels.

5.1.2.2 Orbiter Support Equipment - Beside the primary Orbiter equipment discussed above, which are used to control the payloads from the AFD (panel R11), several other types of Orbiter equipment may be utilized during mission operations. A payload recorder, the controls for which are mounted in the AFD, is assigned to payload use. It can record up to 14 channels of 1 Mb data, resulting in up to 58 min. of data.

The Orbiter CCTV system may be utilized to simultaneously display up to four independent pictures on two 4.75 x 6.3-in. display screens. A total of seven video signals (four assigned to Orbiter and three assigned to payloads) may be selected via switches at the D&C panel on the OOS to obtain up to four video pictures.

A firm requirement to have payload video displayed at the PSS has been established. The ability to select the particular video signal to be displayed is required at panel L11. The use of STS equipment consisting of a Spacelab CRT at L10 and an Orbiter CRT at L11 (modified to receive video) will require one video signal at L11 and a switch at L11 to select the appropriate payload video picture. If a new development MFDS is utilized at the PSS with a CRT at L10 and L11, two video signals may be required. A switch at L11 will be required to select the appropriate video signal.

The requirement to have payload video displayed at the PSS is an impact to the Orbiter CCTV switch box and associated cabling. The CCTV switch box will require two additional video outputs and an additional number of video select input wires. The switching matrix within the CCTV switch box will need to be expanded to provide the routing of the three incoming payload video signals to the two CRTs at the PSS. Cabling from the CCTV switch box to other CCTV components will have to include the additional wires required from the MSS to the video switch box. There is enough payload wiring available between the PSS and MSS distribution panels to support this video requirement.

For those payloads which require more than three video signals a separate video switch box can be added to select the desired video signal. Using a 12-position rotary switch at the PSS up to 12-video signals could be selected. The 12 TSP required would be routed from the PSS through the bulkhead via one of the mission-unique connections.

The Payload Signal Processor (PSP) and the Payload Interrogator (PI) for RF communications will provide a command and telemetry data link for attached and free-flying payloads. The command link is limited to 2 Kbs of information rate, while the telemetry is 16 Kbs. The telemetry signal is routed through the payload data interleaver (PDI) and PCMMU for either downlink or GPC/IOP operations. The command uplink routes through the NSP, MDM, and PSP to reach the attached or RF payload interfaces.

The network signal processor (NSP) is the central point for all uplink and downlink transmissions to the ground. All payload telemetry for downlink is routed through the NSP to the Orbiter GPC/IOP for decoding and subsequent transmission to the payloads via the MDM and PSP.

5.1.3 Spacelab Command and Data Management Constraints - This section is limited to a discussion of the Spacelab equipment which is utilized at the AFD in support of payload mission operations. Emphasis will primarily be on the equipment which interfaces with the C&D; however, other related Spacelab equipment will be briefly mentioned. Figure 5-1, the AFD Systems Interfaces, will be utilized as a reference for the equipment discussions in the remainder of this section.

5.1.3.1 Spacelab AFD Utilized Equipment - As in the Orbiter system, the two Spacelab computers (SLC) and input/output processors (IOP) are the key to utilization of Spacelab equipment. The computers will contain systems software which will allow communications with all peripheral devices such as the CRT display, alphanumeric keyboard, and remote acquisition unit (RAU). The CRT display is a tricolor (red, green, and yellow) with stroke write capabilities. It also has full alphanumeric and some graphic capabilities (vectors, circles). The KB has a full set of alphanumeric keys as well as 25 software controlled function keys. The experiment RAU can communicate with 64 discrete outputs, four serial inputs, four serial outputs and a mix of up to 128 discrete and analog inputs.

The Core Control and Display CCD system located in the AFD can be considered as another peripheral device to the Spacelab main computer.

The integration of CCD will require an extension to the systems software in the experiment computer, allowing communication with the AFD control and display equipment. These software requriements are defined in the flight software CPCEI.

A subsystem RAU is currently baselined for the AFD to support the SL data display unit (DDU), and keyboard KB, as shown below:

	DISCRETE OUT	DISCRETE IN	ANALOG IN	TOTAL
Subsystem RAU Capabilities	64	← 128 →		192
Spacelab Equipment-Subsystem RAU Requirements				
Keyboard		4	2	
DDU		6	6	
Spacelab Total				18

Trade studies investigating the need for this RAU vs the utilization of an experiment RAU in the AFD result in an overwhelming need for an experiment RAU. The following facts support this conclusion:

a. There is a requirement to support mission-unique equipment in the AFD from the experiment computer.

b. The PSS study has been directed to include a panel of MMSE at L12.

c. The Mini-pointing Mount (MPM) and Small Instrument Pointing System (SIPS) are planning to use the experiment computer for pointing command software. This requires the core manual pointing controller (L11) to interface with the experiment computer.

d. There are some indications that the IPS will also use the experiment computer for pointing control.

e. The functional signal requirements for an experiment RAU at the AFD are considerably more extensive than the subsystem RAU requirements, as shown below:

PANEL	FUNCTION	NUMBER OF SIGNALS
L11 A3/4	Event Timers	11
L11 A5	Pointing Control with LED	24
L12 A2	Slewed Digital Display	29
L12 A4	Selectable Meters	13
L12 A5	Selectable Switches and Indicators	72
	AFD CCD Subtotal	149
	Mission-unique Capabilities	51

Then incorporating an experiment RAU at the PS, it should be considered as one of the eight currently serviced by the ECOS software. This implementation approach will eliminate the need to modify the ECOS software which services the RAU interface.

5.1.3.2 Spacelab Support Equipment - The mass memory unit is available to payloads for storage of mission-unique applications software which is not currently being utilized. This can include processing programs, display formats, and mission timeline procedures. In addition, large data bases can be stored for reference by application programs allowing the MFDS processor to be loaded with mission-unique data prior to and during the mission. The memory can store up to 1.31×10^8 bits of information on eight tape files. The average access time within one file is two seconds. When acquired the data transfer rate is about 1 Mb/S.

The power distribution box located at the payload station supplies power for all Spacelab equipment in the AFD (two displays, two electronics units, one experiment RAU, and the backup IPS panel).

Recent SL design changes are resulting in repackaging of the Spacelab power distribution box integral with the keyboard. Preliminary assessment of the resulting increased volume would indicate that there is room for both the subsystem and experiment RAUs at the PS.

A small emergency panel is provided for backup control of the instrument pointing system (IPS). This panel is located at the on-orbit station and provides a hardwired manual operation of the IPS.

5.2 Selection Criteria and Configuration Options - The candidate C&D components (identified in Task III), which must operate within the identified constraints, were evaluated on a comparative basis using the criteria summarized in Table 5-2. Performance, cost and schedule risks were, in most cases, the determining factors in eliminating individual components and system designs from consideration. The advantages of using equipment already qualified for the STS program--or equipment used in identical or similar form on other NASA programs--together with proper utilization of baselined Orbiter or Spacelab equipment and systems in the AFD, allowed formulation of AFD C&D configuration options (for the PS) shown in Figure 5-2. All options baselined the use of a Spacelab CRT and keyboard at R12 (MS) and a row of switches at A7 (OOS), plus MMSE at L11 and L12.

5.3 Configuration Trade Study Summary - The four options identified are similar to each other, as complete systems, but interface compatibility and functional differences do exist. The principal trade study analysis involved the use of the various CRT/keyboard configurations available as multifunction display systems.

Option 1 utilizes two Spacelab CRTs and keyboards at panels L11 and L10. The CRTs provide a tricolor format with full alphanumeric/graphic capability. Due to the large size of the CRT/keyboard in the Spacelab configuration, however, only limited panel space is available (at L12) for MMSE and mission-unique C&D. This option does not provide for a video capability at the PS, which is a firm payload requirement for many missions.

Option 2 utilizes Orbiter CRTs/keyboards at panels L11 and L10. The keyboards employ function keys only, as opposed to the full alphanumeric Spacelab keyboard. The smaller size of the Orbiter CRT/keyboard configuration expands the area available to MMSE or mission-unique C&D. Neither tricolor nor video capability is available with this option.

Table 5-2 Selection Criteria and Rationale

CRITERION	RATIONALE
PRIMARY	
Performance	Ability to meet payload requirements.
Cost	Desire for low cost system--initially and operationally.
Schedule Risk	Ability to meet need dates.
SECONDARY	
Physical (Performance)	Compatibility with Orbiter constraints/resources.
Commonality (Cost/Schedule)	Provides flexibility, cost, schedule, spares, maintenance, servicing, procurement advantages.
User Integration (Cost/Schedule)	Impacts user acceptance, operational era costs.
Foreign vs Domestic (Cost/Schedule)	Impacts maintenance, servicing, initial procurement.
Turnaround Time (Cost/Schedule)	Impacts quantity of units needed, operational era costs.

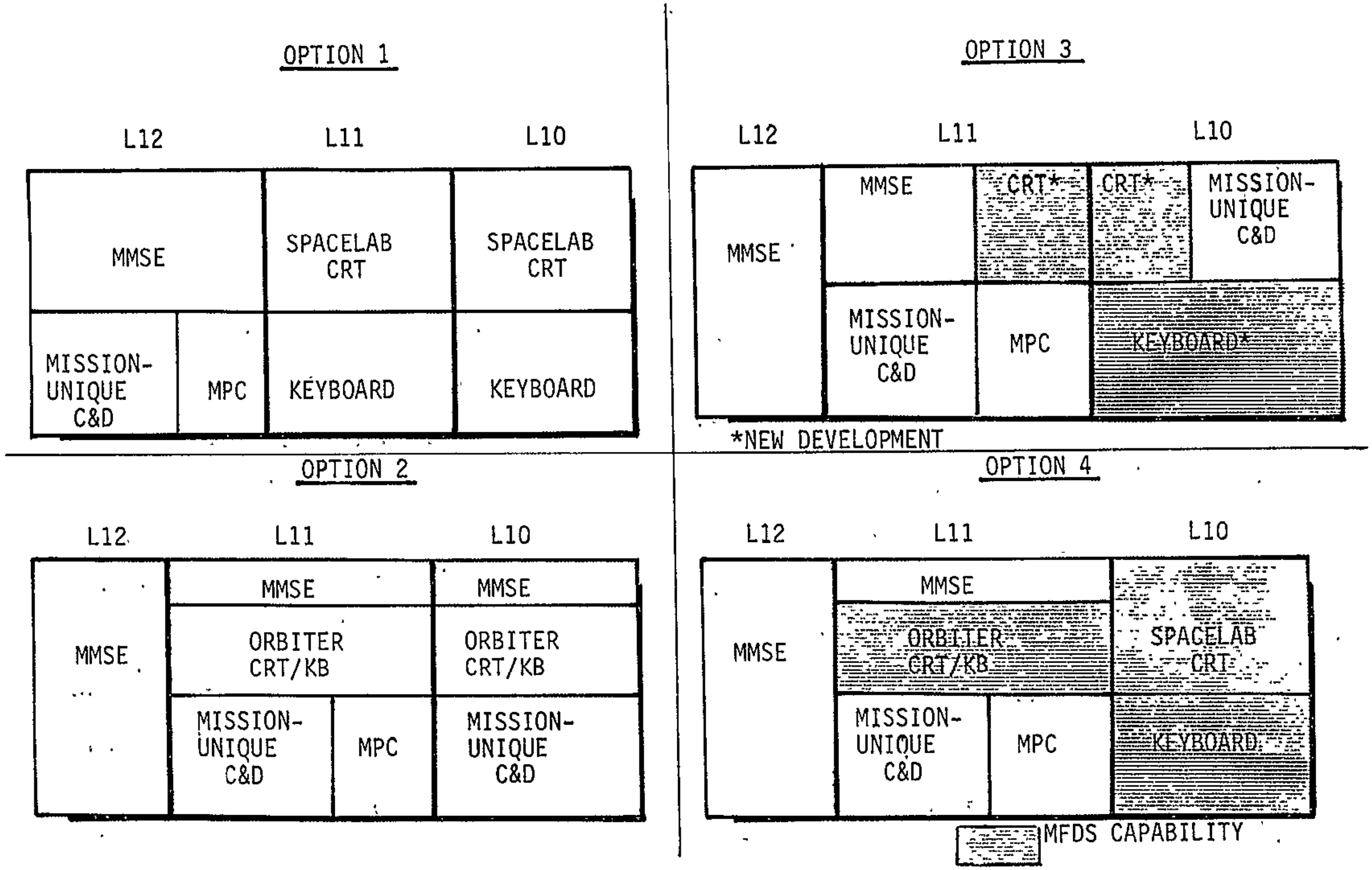

Figure 5-2 AFD C&D Configuration Options

Option 3 employs a new-development MFDS, which provides video (black and white) with alphanumerics/graphics overlays capability on one CRT, tricolor format (alphanumerics/graphics) on the other CRT, and a full alphanumeric keyboard. This option maximizes the area available to MMSE and mission-unique C&D on panel L11 and L12. The MFDS in Option 3 also utilizes less electrical power than the other options, but does involve development risk.

Option 4 utilizes the Spacelab CRT/keyboard hardware at panel L10, and an Orbiter CRT/keyboard--modified to include a video capability--at panel L11, which together provides a MFDS capability. This option allows some MMSE and mission-unique C&D to be located on panel L11, but does not provide as much such space as does Option 3.

Table 5-3 summarizes the characteristics of the MFDS components utilized in Options 3 and 4, and Table 5-4 summarizes the advantages and disadvantages of the four options. Based upon the above considerations, the efficiency of incorporation of the various options into the existing Orbiter/Spacelab system, and the direction received at the study Concept Review (June 24, 1976), Options 3 and 4 were selected for preliminary design.

Both options selected for preliminary design utilize MMSE at panel L12, and in portions of panels L11 and A7. The MMSE provides several advantages in the performance of payload operations. Power limitations in the AFD preclude the use of a third CRT at the payload station; therefore, the MMSE (which uses 50 watts) is required to allow control and monitoring of payload functions in addition to those displayed on the CRTs at panels L11 and L10. Hardwired switches, which form a part of the MMSE set, provide direct control of critical payload parameters, such as the application of high voltage power to a payload instrument. Other MMSE, such as slewable digital displays and event timers, allow direct monitoring of payload operations while other experiments are activated or monitored on the CRTs. The use of a manual pointing controller as part of the MMSE is dictated by the many identified requirements for instrument pointing.

Table 5-3 Multifunction Display Systems Summary

COMPARATIVE FACTORS	MFDS (IBM/NORDEN) - ORBITER	MFDS (BENDIX)	SPACELAB CRT/KEYBOARD
Size of Screen	5" x 7"	8.5" x 11"	7.5" x 10"
Color	No	No	Yes: Red-Green-Yellow
Resolution	83 lines/in.(416 lines)	60 lines/in. (525 lines)	
Power - On (watts)	313	170	290
Power - Standby (watts)	20	20	50
Voltage	28 volt DC, 5 volt DC	115 Volt, 400 Hz	115 volt, 400 Hz
Weight (lbs)	66	105	65
Number of Keys	32 Keys ACS II keyboard + special symbols	60 Keys ACS II keyboard + special symbols	78 Keys ACS II keyboard
Resolution - Alphanumeric	• Large characters-22 lines, 43 characters • Small characters-26 lines, 51 characters	25 lines, 50 characters Status line-top line Address-bottom 2 lines	21 lines, 47 characters
Graphics--geometric patterns, circles, and vectors	• Vectors (variable length) • Circles (variable diameters)	• Vectors (variable length) • Circles (variable diameters)	• Vectors • Circles
Video	Hardware modification required	Yes--EIA RS 330 standard format	No
Video with Alphanumeric Overlay	Hardware modification required	Yes	No
Video with Graphic Overlay	Hardware modification required	Yes	No
Size of Display and Keyboard	Width, 14.9"; Height, 7.4"	Width, 18.0"; Height, 21.8"	Width, 19.0"; Height 24.0"

Table 5-4 Advantages and Disadvantages of the Four Options

OPTION 1 ADVANTAGES • QUALIFIED HARDWARE, ESA • FULL ALPHANUMERIC KB • TRICOLOR CRT DISADVANTAGES • SIZE OF CRT/KB • REDUCTION OF MMSE AND MISSION-UNIQUE C&D PANEL AREA • LACK OF VIDEO CAPABILITY	OPTION 3 ADVANTAGES • 50% LESS POWER REQUIRED • VIDEO CAPABILITY • OVERLAY CAPABILITY • FULL ALPHANUMERIC KB • 8.5" x 11" CRT, CAPABILITY FOR 1000 LINES • INCREASE IN AREA AVAILABLE FOR MMSE AND MISSION-UNIQUE C&D DISADVANTAGES • NEW DEVELOPMENT • QUALIFICATION REQUIRED • RISK
OPTION 2 ADVANTAGES • QUALIFIED HARDWARE, ORBITER • SIZE OF CRT/KB • INCREASE IN AREA AVAILABLE FOR MMSE AND MISSION-UNIQUE C&D DISADVANTAGES • KEYBOARD CONFIGURATION • LACK OF VIDEO CAPABILITY (CCTV AVAILABLE, BUT NOT OPTIMUM FOR PSS) • LACK OF TRICOLOR CAPABILITY	OPTION 4 ADVANTAGES • ORBITER CRT, VIDEO MOD. - LOW COST OPTION • SPACELAB CRT: TRICOLOR • SPACELAB KB: FULL ALPHANUMERIC • MMSE AND MISSION-UNIQUE C&D DISADVANTAGES • SIZE OF SPACELAB CRT/KB

The specific compontns of MMSE required within the core concept were identified by analyzing study payload C&D utilization requirements for complete missions. An optimum MMSE complement consistent with the power and wiring limitations in the AFD was identified by analyzing the requirements of the driver missions (see Section 3.4.4), the Spacelab 2 mission, and a DOD/IUS mission. AFD payload C&D utilization summaries were generated for those missions in the format shown in Figure 5-3. The summary sheets were intended to show how a particular mission (payload complement) would utilize the AFD C&D available. The left hand column lists the major functional requirements for a particular instrument or experiment. The next three columns list the AFD location, type, and description of the specific control and/or display which satisfies the functional requirement listed. Subsequent columns identify the type of command or response which the function requires, describes how the response is displayed, and identifies the mode in which the C&D signals travel across the systems interface.

For example, activation of power to a subsystem via a CRT/keyboard input requires two bilevel commands (on/off) (2B/). The display of the command could be part of a procedural page (text) on the CRT. The response of a monitoring (voltage, current) function for that command requires two proportional (/2P) signals as feedback which could also be displayed as part of a text page. The systems interface in this case is the data bus between the CRT/keyboard unit and the controlling computer.

C&D utilization is summarized for complete missions (not just single payloads) to ensure total requirements for specific controls or displays do not exceed the equipment available. Table 5-5 shows the complete C&D utilization requirements for the six missions analyzed. This trade study allowed identification of the MMSE set shown in Table 5-6.

5.4 Spacelab Digital Tape Recorder - Location Options Trade Study - Included in this study was an analysis as to the most feasible location within the AFD to

MISSION: SPACELAB 2		EXPERIMENT: COSMIC X-RAY TELESCOPE (SKYLARK)				
FUNCTIONAL REQUIREMENT CONTROL AND DISPLAY	AFD PANEL LOCATIONS	EQUIPMENT UTILIZED		DATA TYPES		SYSTEMS INTERFACE
		S/M	EQUIPMENT DESCRIPTION	COMMAND/RESPONSE	DISPLAY	
• ACTIVATE INSTRU. POWER (ON/OFF)	L12-A1	S	MOM 2-POS SW + IND	2B/1B	IND	HW
- MONITOR VOLTAGE/CURRENT	L10	S	CRT	/2P	T	DB
• ACTIVATE DETECTOR POWER (ON/OFF)	L12-A5	S	MOM 2-POS SW + ROT SW	3B/2B	IND	DB
- MONITOR VOLTAGE, CURRENT	L10	S	CRT	/2P	T	DB
• ACTIVATE THERMAL CANISTER POWER (ON/OFF)	L12-A5	S	MOM 2-POS SW + ROT SW	3B/2B	IND	DB
• ACTIVATE INSTRU. RESTRAINTS (ENGAGE/DISENGAGE)	L12-A3	S	LKD SW	1B/	-	HW
• ACTIVATE L^3TV (SEE APPLICABLE LISTING)						
• PERFORM PTG. (MPM & L^3TV)	L11-A2/ L11-A5	S	CRT + MPC + SWs		V	
- ACTIVATE MPC/SELECT MPM	L11-A5	S	2 POS MOM SW + ROT SW	2B/	-	DB
- ELEV/AZIMUTH PTG.	L11-A5	S		2P,3B/	-	DB
- MONITOR GIMBAL ANGLES	L12-A4	S		2B/3P	METER	DB
• ACTIVATE DATA TAKE (START/ STOP)	L10,L12-A1	S	CRT/KBD	2B/1B	T,IND	DB

B-Bilevel; P-Proportional; A-Alert; ROT-Rotary; HW-Hardwired; DB-Data Bus;
S-Standard AFD Equipment; M-Mission-unique (payload provided); SW-Switch; LKD-Locked;
MOM-Momentary; IND-Indicator; T-Text; MPC-Manual Pointing Controller

Figure 5-3 Example of AFD C&D Utilization Summary

Table 5-5 Complete AFD C&D Utilization by Driver Missions

PANEL	CORE CAPABILITY	ASTRONOMY FACILITY	DSSM	BESS/ GRS/SMM	DOD/IUS	BESS/ AUTO LEV/DWS	SL2
L12-A1	10 switches/indicators	10	10	---	10	---	10
L12-A2	Rot. SW + Display - 22 Pos.	10	2	10	---	---	2
L12-A3	18 Lkd SW, 6 with Ind.	16	10	6	10 (5 with ind)	11	11
L12-A4	Meter display - 11 pos.	6	8	---	---	---	2-4
L12-A5	SW + Rot. - 33 pos. + 5 potentiometers	30 2	31 5	8 ---	--- ---	4 ---	19 2
L11-A1	Mission-unique	---	X-ray CRT	---	---	---	X-ray CRT
L11-A2	CRT/KBS with video	~20	~10	---	---	---	~15
L11-A3, -A4	2 event timers	~10	~5	---	---	---	
L11-A5	Manual Pointing Controller	~10	~10				~5
R12/L10	CRT/KBD, tricolor	~125	~70	---	---	~20	~65
A7-A1	12 lkd SW	6	7	9	---	7	4-8

Table 5-6 Description of MMSE Set for AFD Core Concept

SUBPANEL DESIGNATION	COMPONENT DESCRIPTION	QUANTITY
L12-A1	• 2-position momentary toggle switch • 3-position event indicator • 3-position toggle switch	13 10 1
L12-A2	• 12-position rotary switch • 5-character programmable digital display • 2-position momentary toggle switch • 15-character programmable alphanumeric display • 10-character programmable alphanumeric display	2 2 2 2 2
L12-A3	• 2-position locked toggle switch • 3-position event indicator	18 6
L12-A4	• 12-position rotary switch • Horizontal analog meters	1 3
L12-A5	• Potentiometer, single turn, friction • 12-position rotary switch • 2-position momentary toggle switch • 3-position event indicator	5 3 9 9
L11-A3	• Event timer • 10-character programmable alphanumeric display • 2-position momentary toggle switch	1 1 3
L11-A4	Same as L11-A3	Same as L11-A3
L11-A5	• Manual pointing controller • 12-position rotary switch • 2-position momentary toggle switch • 3-position toggle switch	1 1 2 1
A7-A2	• 2-position locked toggle switch	12

locate the Spacelab high rate digital recorder. The analysis included an assessment of the impact on the core C&D concepts and Orbiter systems due to recorder interface wiring, power required, weight, size, and location. There were six options studied, each locating the recorder at various positions within the AFD. The advantages and disadvantages of each option are summarized below. Option 4 is the recommended option, placing the recorder at panel L12.

In Option 1, the recorder (Transport Unit and Electronics Unit) was located at the MS at panel R12. Although this provided an acceptable weight and power impact, the RAU interface required an unacceptable crossover wiring impact. Locating the recorder at R12 would also prevent a Spacelab display unit capability at the MS (required to provide simultaneous independent operation of experiments from the AFD).

In Option 2, the recorder was located at panel L12. The transport unit was located on the L15 panel area and the electronics unit was located within panel L12. This option provided an acceptable weight and power impact, but the inability to change tapes and the loss of L12 panel surface area (8-in.), which would normally contain MMSE, made this option unacceptable.

In Option 3, the recorder (Transport Unit and Electronics Unit) was located within the L12 panel. This option also provided an acceptable weight and power impact, but the inability to change tapes and the restriction of the L12 panel depth to only 8-in. was unacceptable.

Option 4 is the recommended option; the recorder being located at panel L12. The transport unit is located on the L12 surface area and the electronics unit is located below the transport unit. This option eliminates most of the MMSE at L12, but has the capability to change tapes and provides an acceptable weight and power impact. This option requires less prime panel surface than if the recorder was located at any other panel.

In Option 5, the transport unit is located along with the Spacelab CRT and keyboard at panel L10. The electronics unit is located at the bottom of the L12 panel volume. This option provided the capability to change tapes

and made the L12 panel surface available for MMSE. However, there was an unacceptable impact on the L10 panel weight and thermal cooling capability. Also, the Spacelab keyboard at panel L10 was raised to an unacceptable height above the panel surface.

In Option 6, the transport unit is located on the L14 panel surface and the electronics unit is located at the bottom of the L12 panel volume. This option also provided the capability to change tapes and made the L12 panel surface available for MMSE. However, the impact on the L11 panel weight and thermal cooling capability, along with the loss of MMSE dedicated C&D area at L11 made this option unacceptable.

6.0 PRELIMINARY DESIGN (TASK V)

The aft flight deck C&D configuration proposed as a result of this study includes the design of five separate panels which comprise a core C&D system. Detailed design requirements of the core C&D are contained in the Part I CEI Specifications (Part II of this volume). In addition, the interfaces between this core system and the Orbiter/Spacelab equipment provided as part of the basic STS system have been defined. The AFD core C&D concept can be implemented by either of two layouts using either STS qualified hardware or new development hardware for the MFDS portion of the core. The two layouts are identical in functional terms and form part of the complete core system, which also includes items of MMSE. (Refer to Figures 1-3 and 1-4.)

The core configuration utilizes the following Spacelab equipment as GFE: CRT/keyboard at the MS (panel R12), instrument pointing system backup C&D at the OOS (A6-A2), an experiment and subsystem remote acquisition unit (mounted within the PS console volumes L16 and L17), the power distribution box (packaged integral with the SL KB), and four data bus interconnecting stations (I/S). If the STS hardware layout is utilized, the CRT/KB at panel L10 and two additional I/Ss are required as GFE.

6.1 Panel Layouts - Figures 6-1 through 6-4 show the panel layouts of the core C&D for STS equipment. Panels L10, L11, and L12 are located at the payload station (PS) in the AFD, panel R12 is at the mission station (MS), and panel A7 is at the on-orbit station. Panel L10 contains a tricolor CRT with a full alphanumeric keyboard (Spacelab version shown). Panel L10 contains a CRT with black and white video and full alphanumeric/graphic overlay capability, together with a secondary function keyboard (STS version shown); this panel also includes two event timers and a manual pointing controller as MMSE, along with space for mission-unique C&D. Panel L12 includes five subpanels of MMSE. An alternate configuration of panel L12 includes incorporation of the Spacelab high rate digital tape recorder (see Figure 6-5) in place of the MMSE on subpanels L12-A2, -A3, -A4 and -A5. An extensive trade study indicated that, if required by a specific mission, the optimum AFD location for the recorder is L12 at the PS. Recent SL program decisions have resulted in placing the recorder in the payload bay.

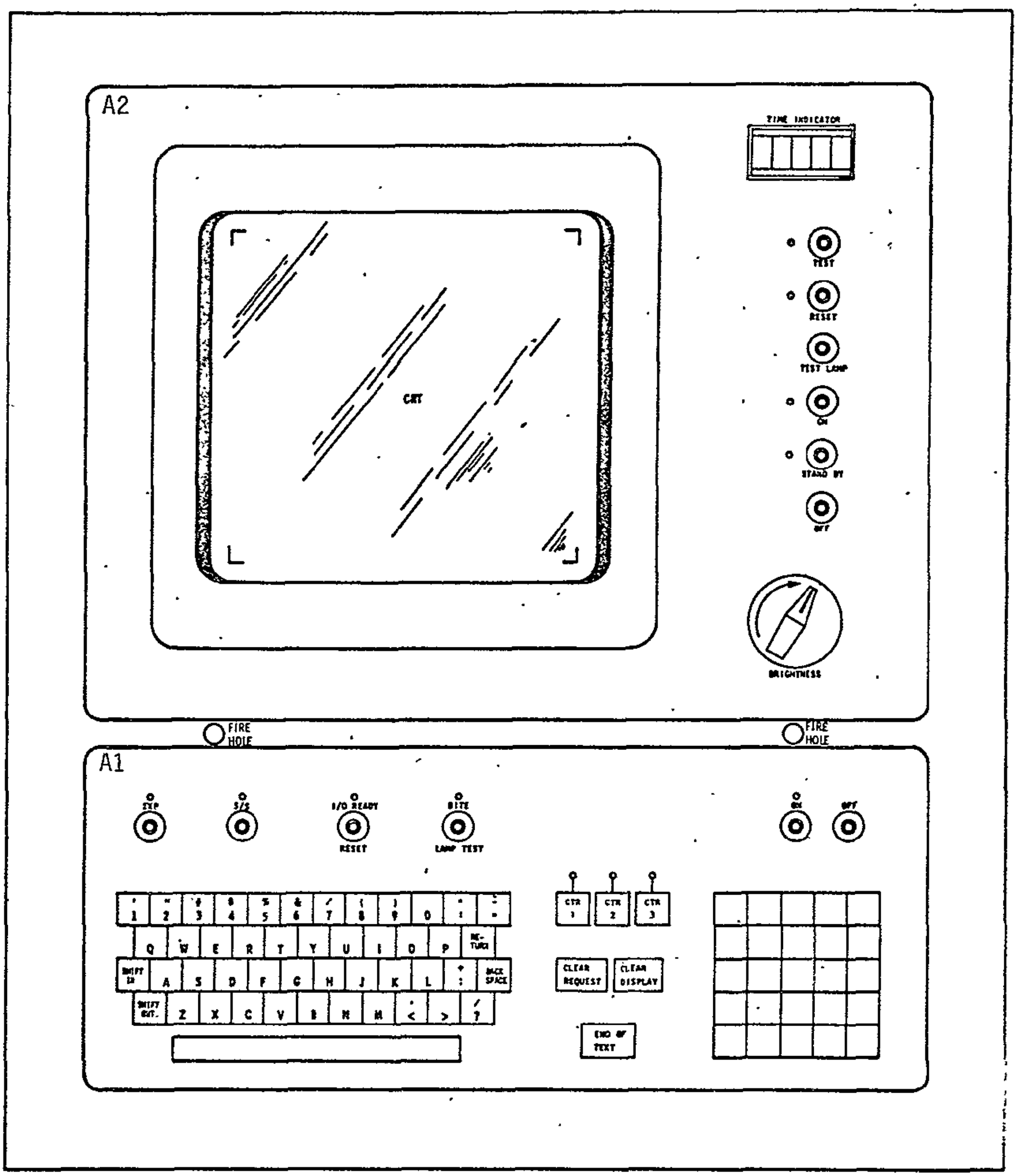

Figure 6-1 AFD C&D Concept - Panels L10 and R12

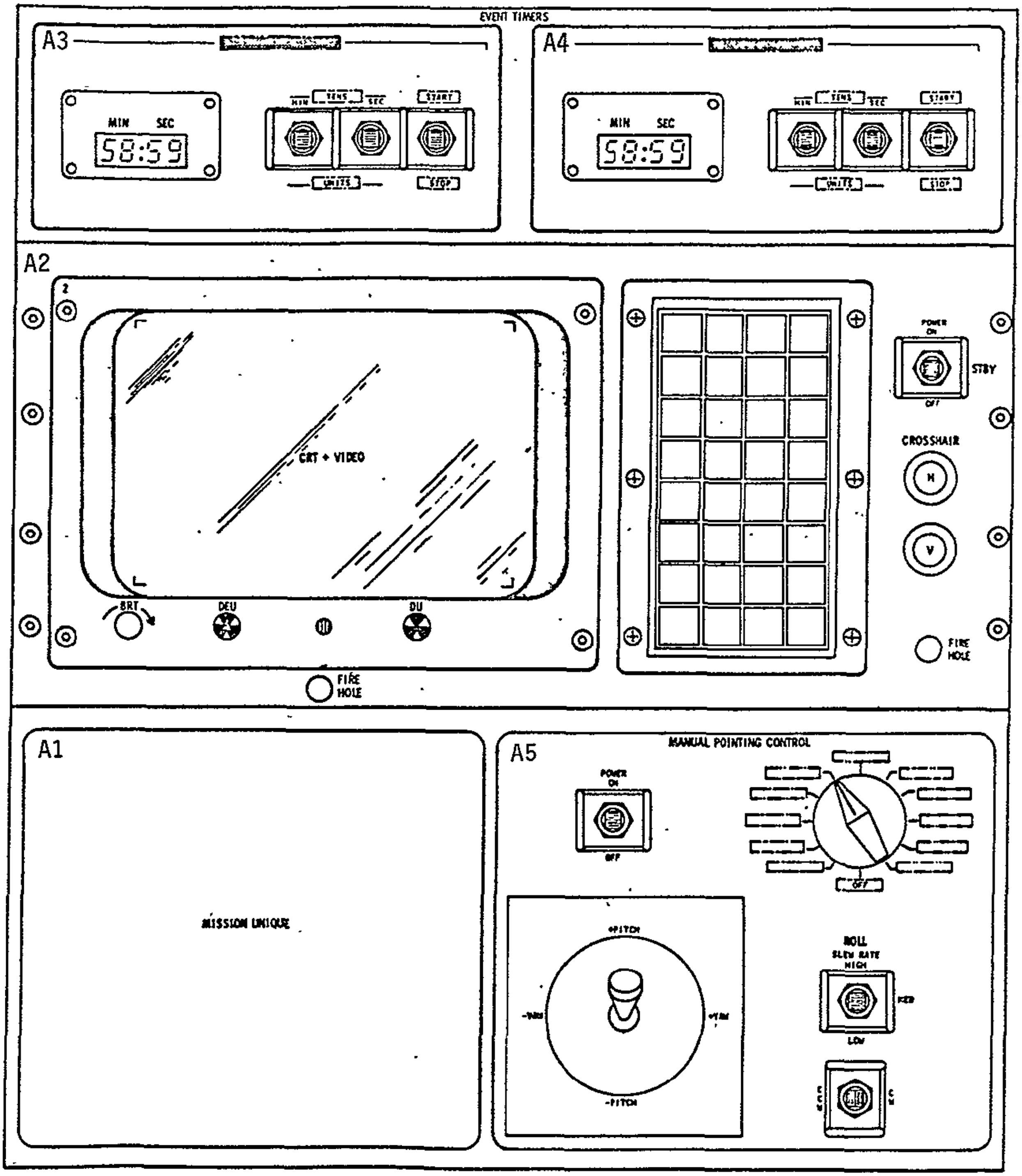

Figure 6-2. AFD C&D Concept - Panel L11

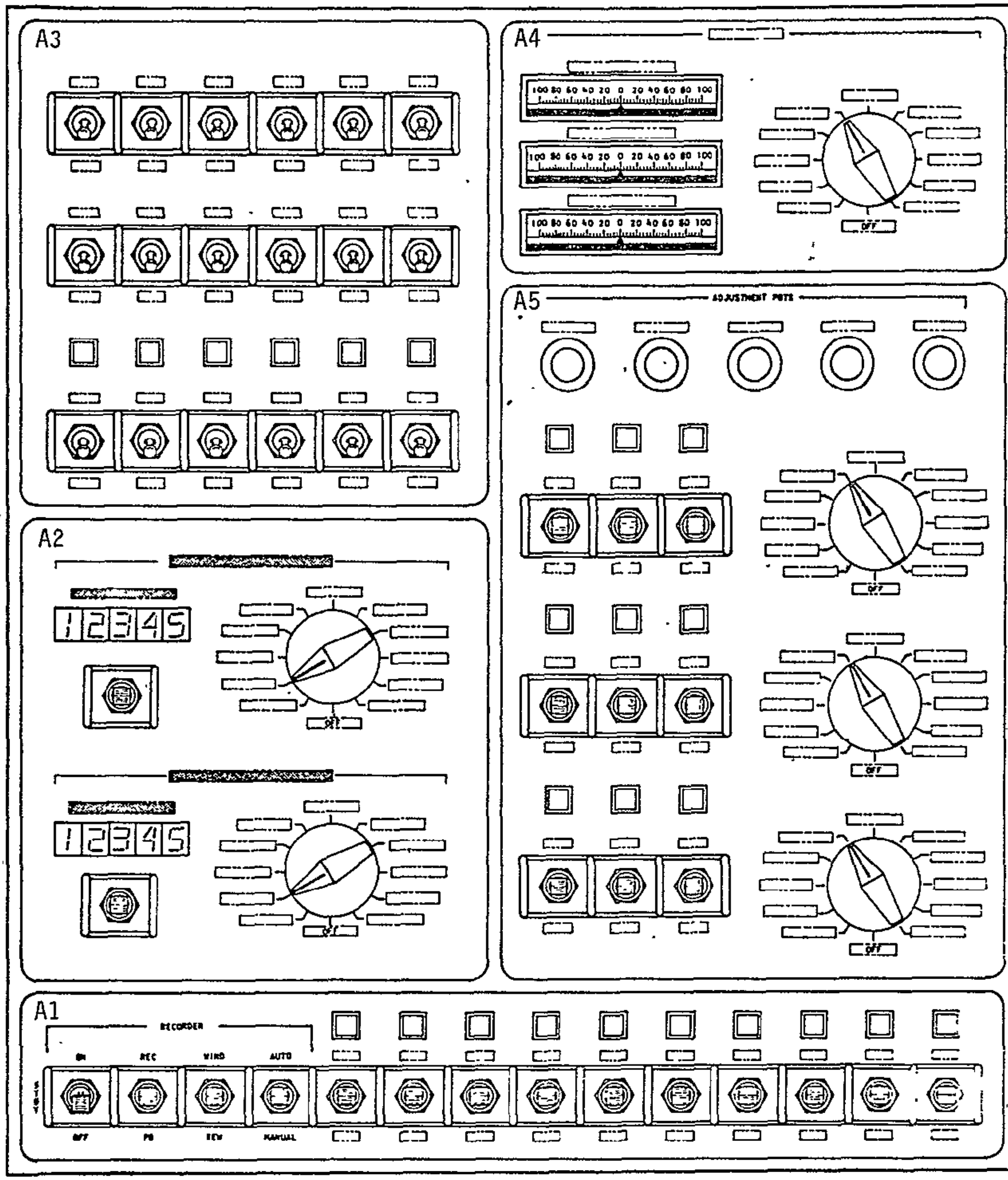

Figure 6-3 AFD C&D Concept - Panel L12

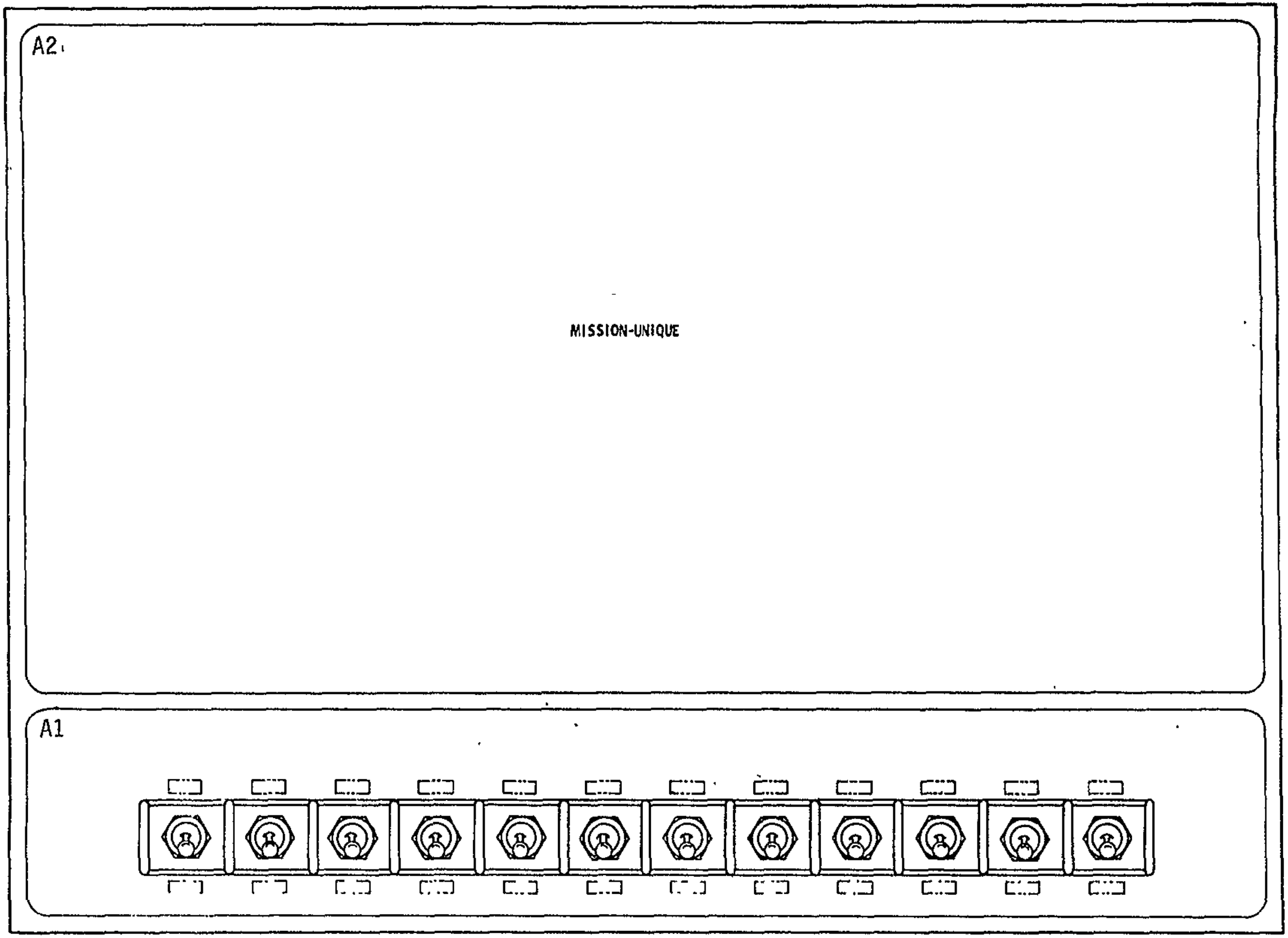

Figure 6-4 AFD C&D Concept - Panel A7

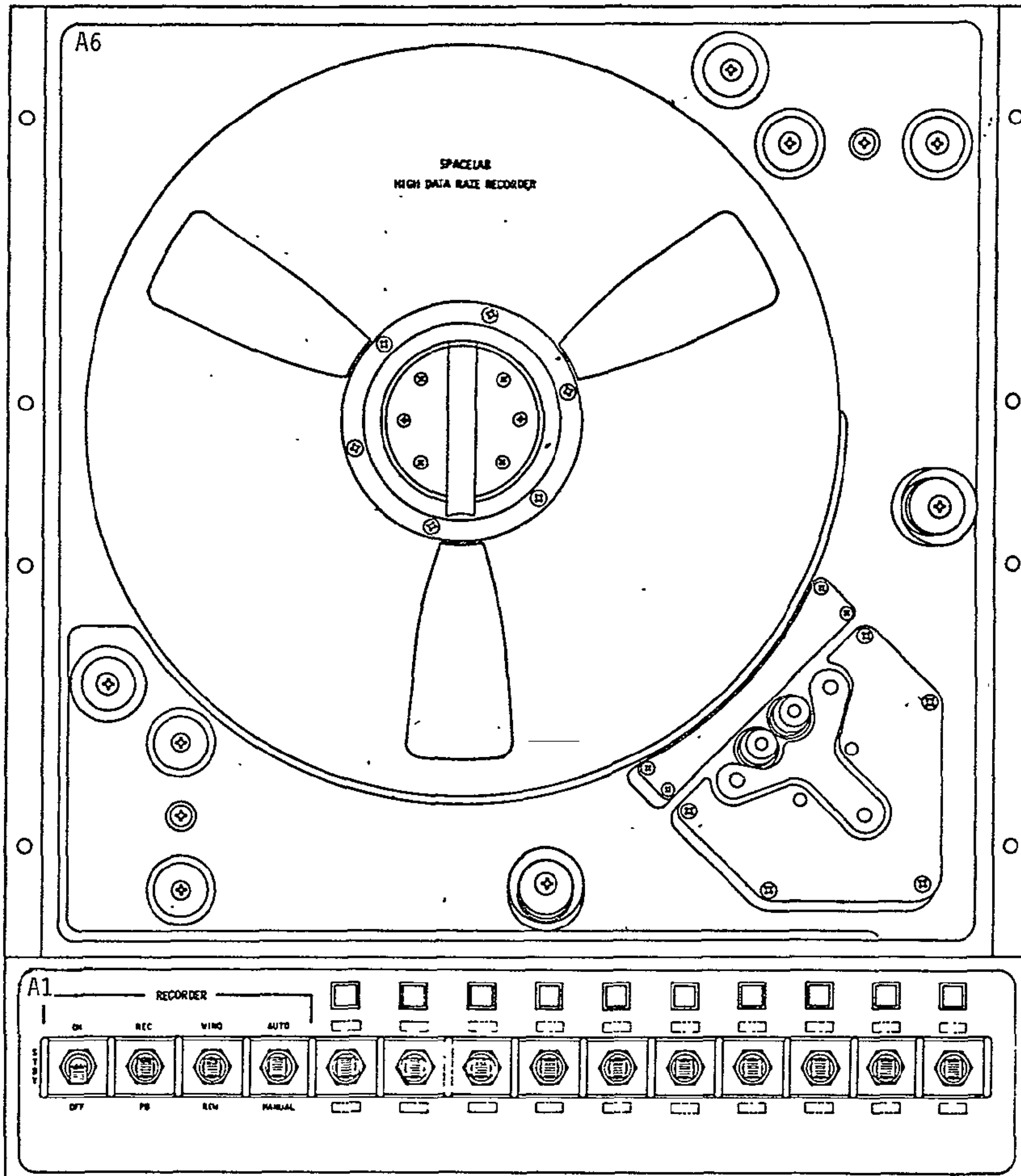

Figure 6-5 AFD C&D Concept - Panel L12 Alternate

Panel A7 at the OOS is only partially utilized by core C&D; a row of switches (MMSE) is located at subpanel A7-A2. Panel R12 contains a Spacelab CRT and keyboard which are functionally equivalent to the core C&D at panel L10 of the PS. Additional panel areas dedicated to payload use and not required by the core C&D are located at R7 (MS), and at A6 and A7 (OOS). The remaining AFD panels are dedicated to Orbiter C&D, some of which (R11, R13, A3) may be utilized by payloads for specific applications.

Figures 6-6 and 6-7 show the panel layouts for the new development MFDS. The two black and white CRTs are controlled from one full alphanumeric and function keyboard. Each CRT can present one video signal with full alphanumeric and graphic overlay capability. Both CRTs will also be capable of controlling pointing via crosshair controls.

The core C&D panels are integrated within the total AFD capabilities for payloads. Interfaces between core C&D and Orbiter or Spacelab systems and hardware interfaces, including electrical power requirements wiring interfaces and component/console weights, have been defined in detail and are discussed in the following sections.

6.2 Systems Interfaces - The proposed core C&D interface with standard Orbiter systems, Spacelab systems, and payload-unique systems--all of which are located in either the AFD or the Orbiter payload bay. Systems interface diagrams for Spacelab and free-flyer payloads, utilizing STS equipment, are shown in Figures 6-8 and 6-9. The interfaces depicted are consistent with the defined interfaces of both the Orbiter and Spacelab systems.

For Spacelab missions (Figure 6-8) the primary interface to the core C&D is thorugh the Spacelab experiment and subsystem computers located in the igloo in the payload bay. In addition, significant capability exists to hardwire functions directly to a payload or instrument in the payload bay.

For free-flyer missions (Figure 6-9) the Spacelab computational systems are not available, and the core C&D interfaces either to the Orbiter GPC, to a payload-provided computer, or directly with the payload via hardwires. Specific configurations are dependent on ovall mission requirements.

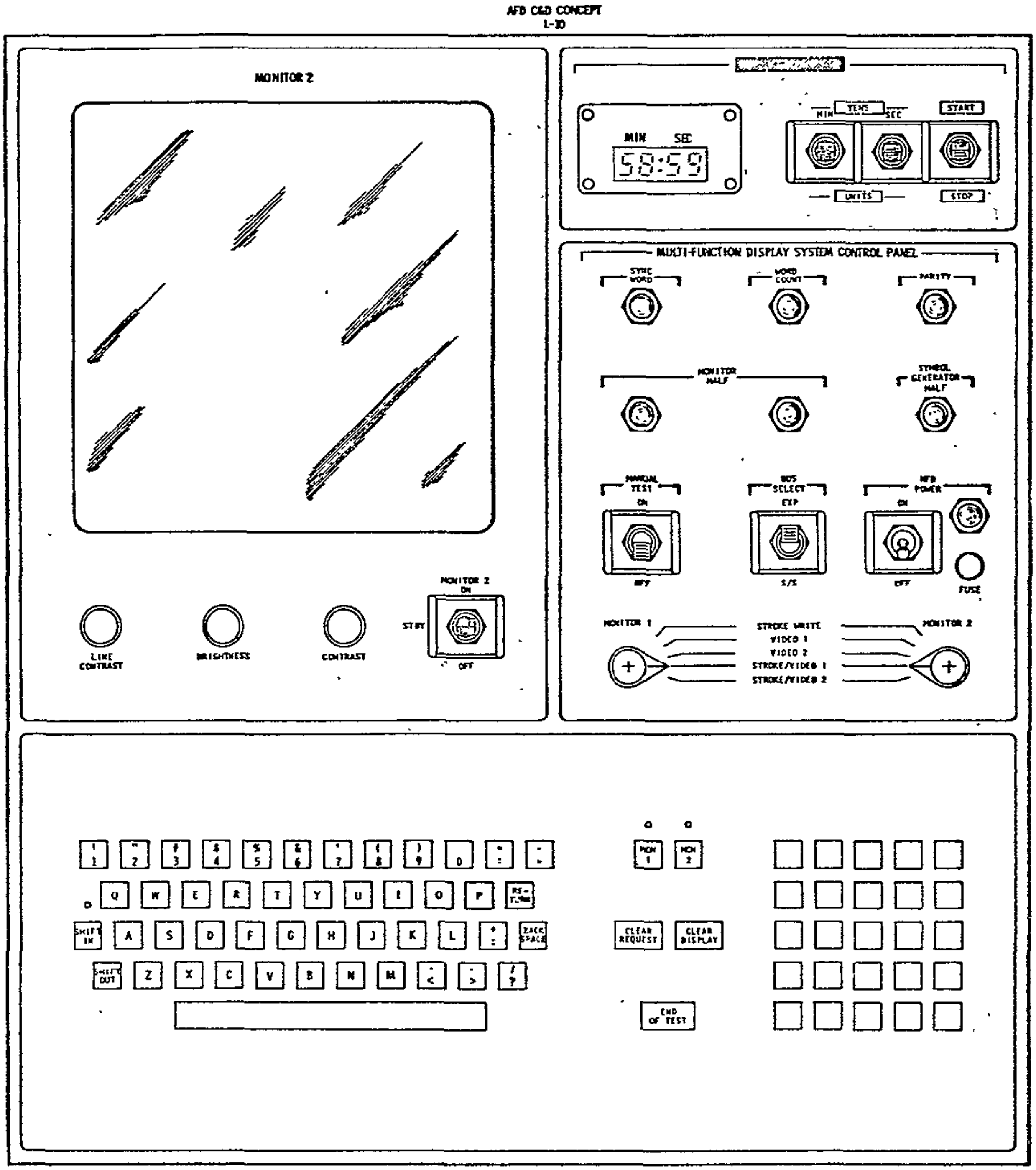

Figure 6-6 Panel L10, New Development MFDS

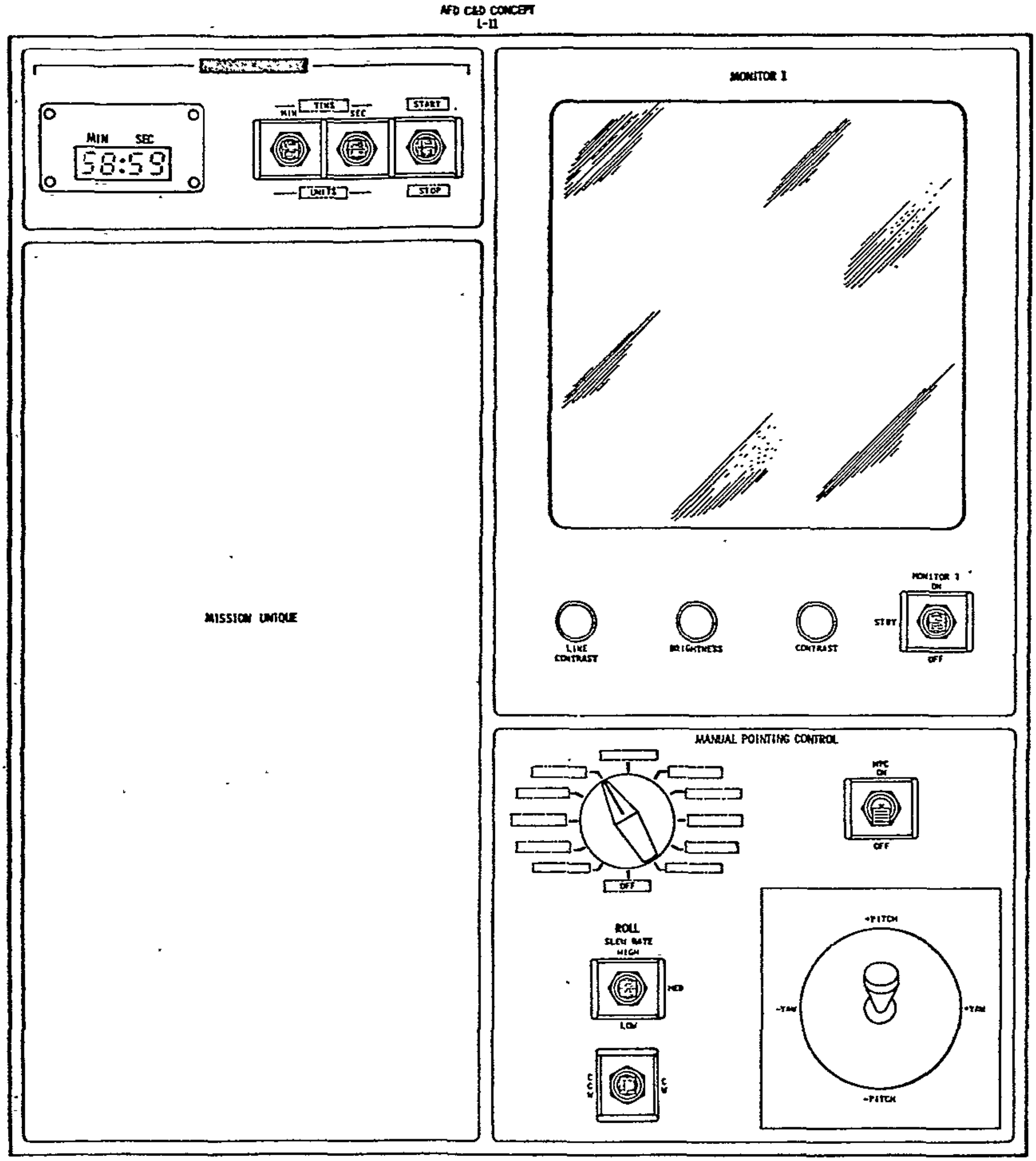

Figure 6-7 Panel L11, New Development MFDS

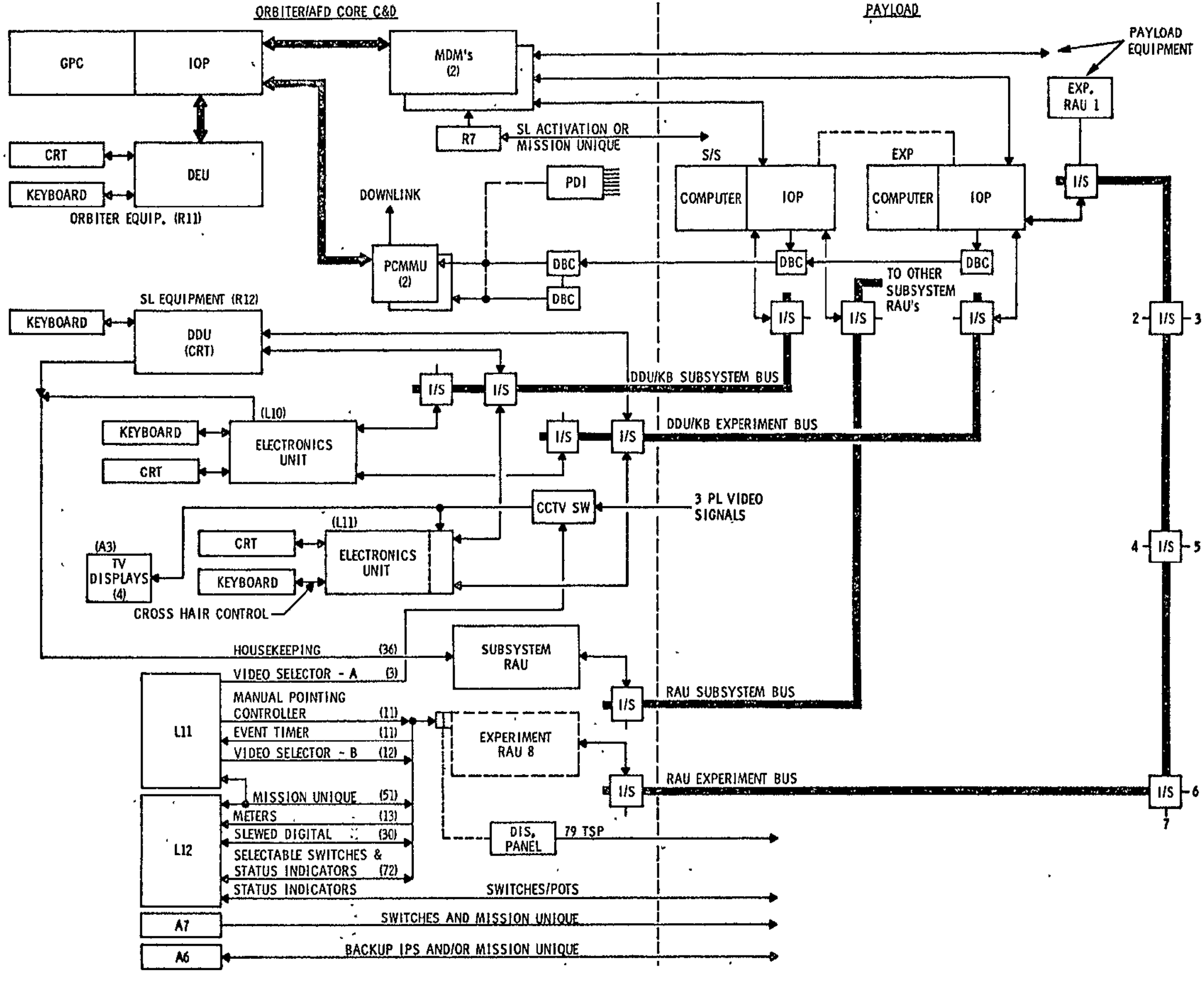

Figure 6-8 AFD CCD Systems Interface - Spacelab (STS MFDS)

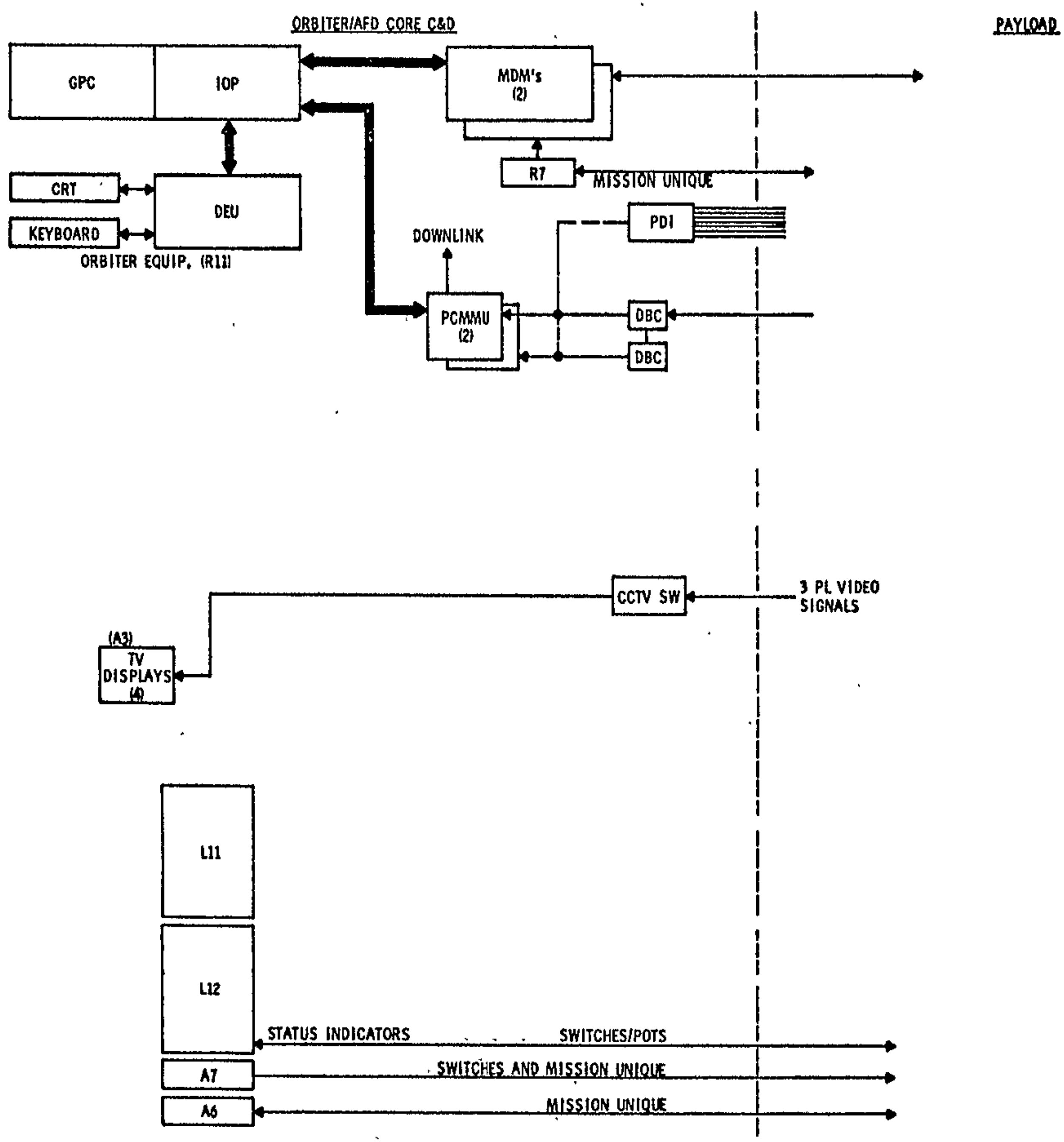

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Figure 6-9 AFD CCD Systems Interface - Free-Flyer/OFT

The equipment in the CCD can be grouped into hardwired, RAU, and display interfaces and will be described in the following paragraphs. The capabilities remain the same as they are for the CCD; however, the utilization of the equipment can vary as a function of the specific mission requirements.

6.2.1 Hardwired Interfaces - The hardwired interfaces are shown in Figure 6-9. All of these interfaces have been wired into connectors on the PS patch panel which contain fixed Orbiter services. This design approach leaves three mission-unique connectors, containing 79 TSP wires, free for future applications.

Panel A6 (Figure 1-3) has been reserved to accommodate the backup IPS controls for Spacelab. Current baseline design of this panel utilizes nine TSP and five TP wires which are routed through the MS bulkhead.

On panel A7 (Figure 6-4) 12 locked switches are hardwired through the PS bulkhead. Each switch uses a twisted pair of wires.

On panel L12 (Figure 6-3) three subpanels contain hardwired interfaces. Subpanel A1 has 10 momentary switches and 10 status indicators. Each of these items interface through the PS bulkhead with two TP wires. Subpanel A1 also contains four switches for Spacelab recorder controls. On missions which require a Spacelab recorder located in the payload bay, these four switches will be hardwired through the bulkhead using mission-unique wiring. Subpanel A3 contains 18 locked toggle switches and six status indicators, which are wired to the PS bulkhead with 18 TP and 12 TP wires, respectively. Subpanel A5 contains five potentiometers, which are routed through the PS bulkhead using two TSP and two TPs.

Panel R7 is assigned to activation together with caution and warning for all Spacelab missions. The non-Spacelab missions (i.e., IUS) requiring this space may also use it for their own mission-unique functions. This panel has 31 TSP and 25 TP wires assigned to the MS bulkhead together with two TSP and two TP wires in the OOS crossover to the PS station.

Section 6.3 will present the wiring between all items of core and mission-unique C&D hardware, and specifies wiring to the bulkhead for all core and mission-unique hradware located at panels L10, L11, L12, A6, A7 and R12.

6.2.2 RAU Interfaces - The RAU interface is used to multiplex many functions to one data bus. An experiment RAU is utilized to service 149 CCD MMSE function and provide the capability for 51 mission-unique functions. The functions and their signal characteristics are discussed in the following paragraphs. The top level software requirements which communicate over these interfaces are defined in the CCD flight software CPCEI.

Panel L12 A2 contains two Slewed Digital (SD) controls and displays. The controls for each SD display consist of a 12-position selector switch and a momentary toggle swithc which interfaces to 14 discrete inputs on the experiment RAU. The displays for each SD display consist of one five-digit numeric and two 10-digit alphanumeric LED displays which interface with two serial digital outputs of the experiment RAU.

Panel L12 A4 contains three analog meters which can present three of 36 mission-unique application software variables for each of the 12 selector switch positions. The meters and selector switch interface with one serial output and 12 discrete inputs of the experiment RAU, respectively.

Panel L12 A5 contains three Selectable Switch and Event Indicators (SSEI) modules. Each module can command and display, with the application software interface, three of 36 functions for each of the 12 selector switch positions. Each SSEI interfaces with 18 discrete inputs and six discrete outputs of the experiment RAU.

Panel L11 A3 and L11 A4 contain the Event Timer (ET) modules. The time set signals for both these modules interface with seven discrete outputs of the experiment RAU. The start and up-down controls each require two additional discrete inputs.

Panel L11 A5 contains the Manual Pointing Controller (MPC) module. A 12-position video and pointing selector switch interfaces with 12 discrete inputs of the experiment RAU. The pointing controls consisting of a pitch-yaw-proportional rate controller and discrete roll control interface with four analog inputs and seven discrete inputs, respectively.

The subsystem RAU interface is used to multiplex 18 DDU/KB housekeeping functions for use by the SL subsystem computer (see paragraph 5.1.3.1).

Section 6.3 will present the wiring interface summary between the RAU and the various items of core C&D at the AFD.

6.2.3 Display Interfaces - Three CRTs and their associated electronics interface with two data buses to form the video, alphanumeric, and graphic display capability in the AFD CCD; Figure 6-8 shows this interface. The CCD Flight Software CPCEI defines top level software requirements for the operation of this interface.

Two buses service the three CRT display units, one for experiment data and the other for subsystem data. The buses that these displays interface on are of Spacelab design. Each bus contains four TSP wires for a primary and a backup channel. Within each of these channels there is one TSP for command functions and another TSP for response functions. The three CRT display units are capable fo communicating on both of the buses through manual selection from the AFD display controls.

Figure 6-10 shows the display interface configuration for new development hardware. It should be noted that only one electronics unit is required, which results in the elimination of two SL I/Ss.

6.2.4 Spacelab Utilization - Figure 6-8 and 6-10 show the combination of AFD CCD interfaces together with Orbiter MDM and telemetry interfaces. This total combination of equipment is required to satisfy the driver Spacelab missions. The Orbiter interface is utilized for Spacelab activation, uplink/downlink communication, and GN&C data transfers. The CCD equipment is utilized for on-orbit payload experiment operations.

6.2.5 Free-Flyer Utilization - Figure 609 shows the portion of AFD CCD interfaces which will be utilized by free-flyer missions. Since these payloads require only an activation and deployment sequence, the total CCD capability is not required. The Orbiter interface is used for GN&C data transfers, telemetry monitoring, and uplink/downlink communication. The hardwired interface is used for payload system activation and deployment sequences.

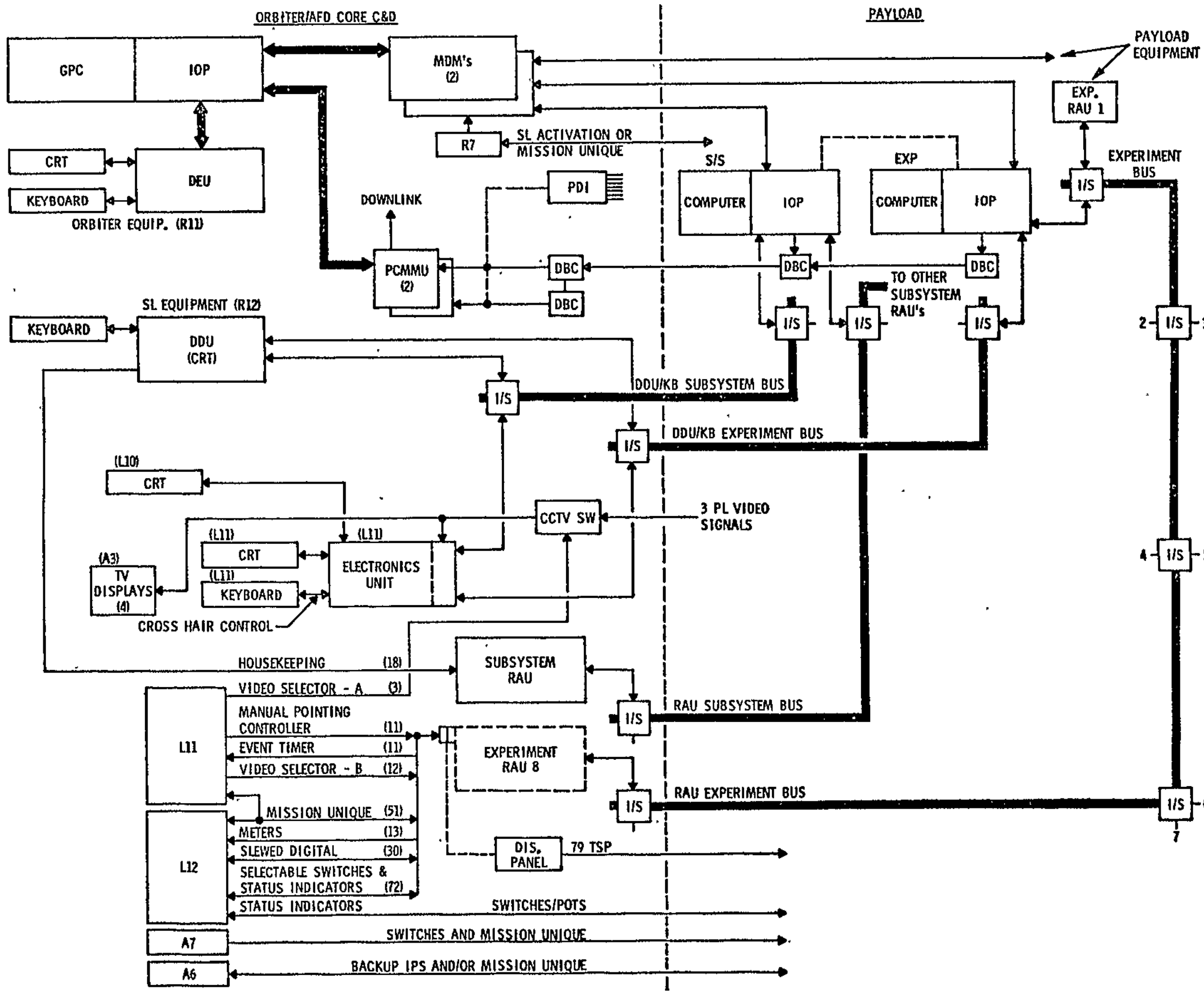

Figure 6-10 AFD CCD Systems Interface - Spacelab (New Development MFDS)

In addition to the basic free-flyer requirements, additional capabilities independent of the Orbiter computer system are available. Figure 6-11 shows the software driven experiment RAU functions, which were previously described in paragraph 6.2.2. These controls and displays are available via a data bus or hardwired interface. If the hardwired interface is required, up to 79 TSP wires are available to connect a selected portion of the MMSE to the payload. It should be noted that this is implemented with a simple removal of the RAU wire harness and installation of a mission-unique harness. If the full MMSE capability is desired by the free-flyer payloads, the RAU data bus interface would be connected to the payload provided computer.

If the free-flyer payload desires an independent CRT/KB display system, a simple connection of their computer to the experiment display data bus is all that is required. This interface is shown separately in Figure 6-12, and integrated in Figure 6-13.

6.2.6 Hybrid Mission Utilization - The hybrid (Spacelab and Free-flyer) missions can be accommodated by the Spacelab configuration (Figure 6-8), since it encompasses the free-flyer interface utilization shown in Figure 6-9.

6.2.7 Early Mission Utilization - For early operational missions or OFT missions where payload and Spacelab computers may not be available, an Orbiter computer interface with MFDS is provided (Figure 6-13). A connection to a Data Bus Coupler (DBC) and the DK-4 display data bus is provided by the Orbiter at the payload station. The MFDS electronics will have an I/O port allowing it to be connected to this DK-4 display data bus. It should be noted that the Orbiter display at panel R11 is also on this bus and Orbiter GPC system software changes will be required to service two displays on one bus.

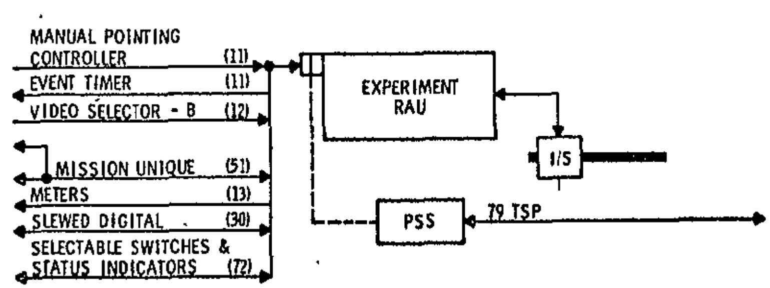

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Figure 6-11 AFD CCD RAU Interface - Free-Flyer/OFT

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OF POOR QUALITY

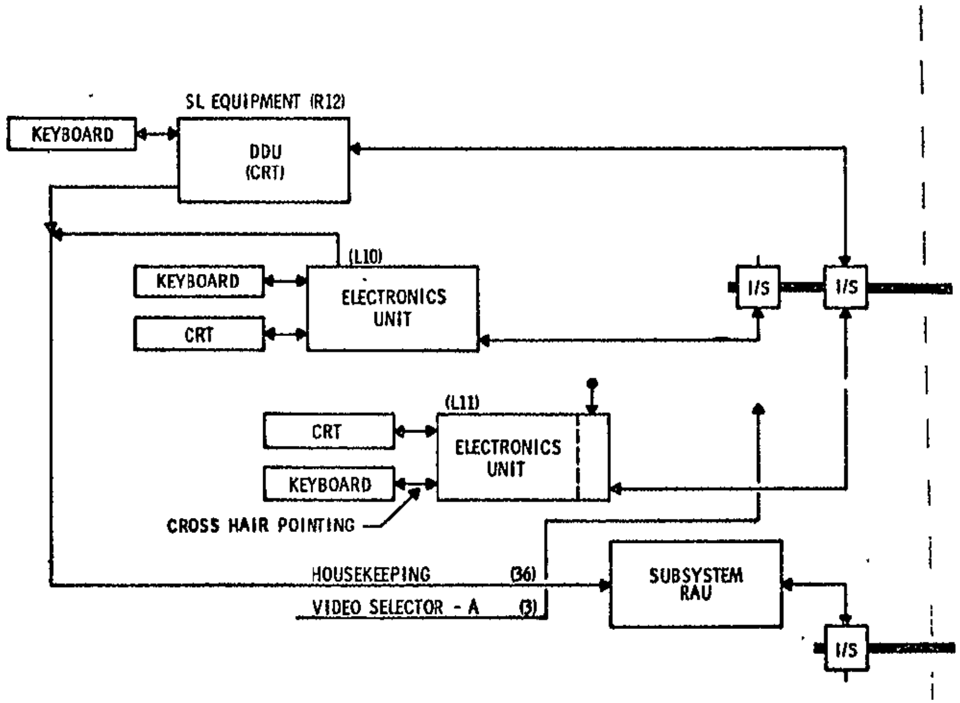

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Figure 6-12 AFD CCD Display Electronics Interface - Free-Flyer/OFT

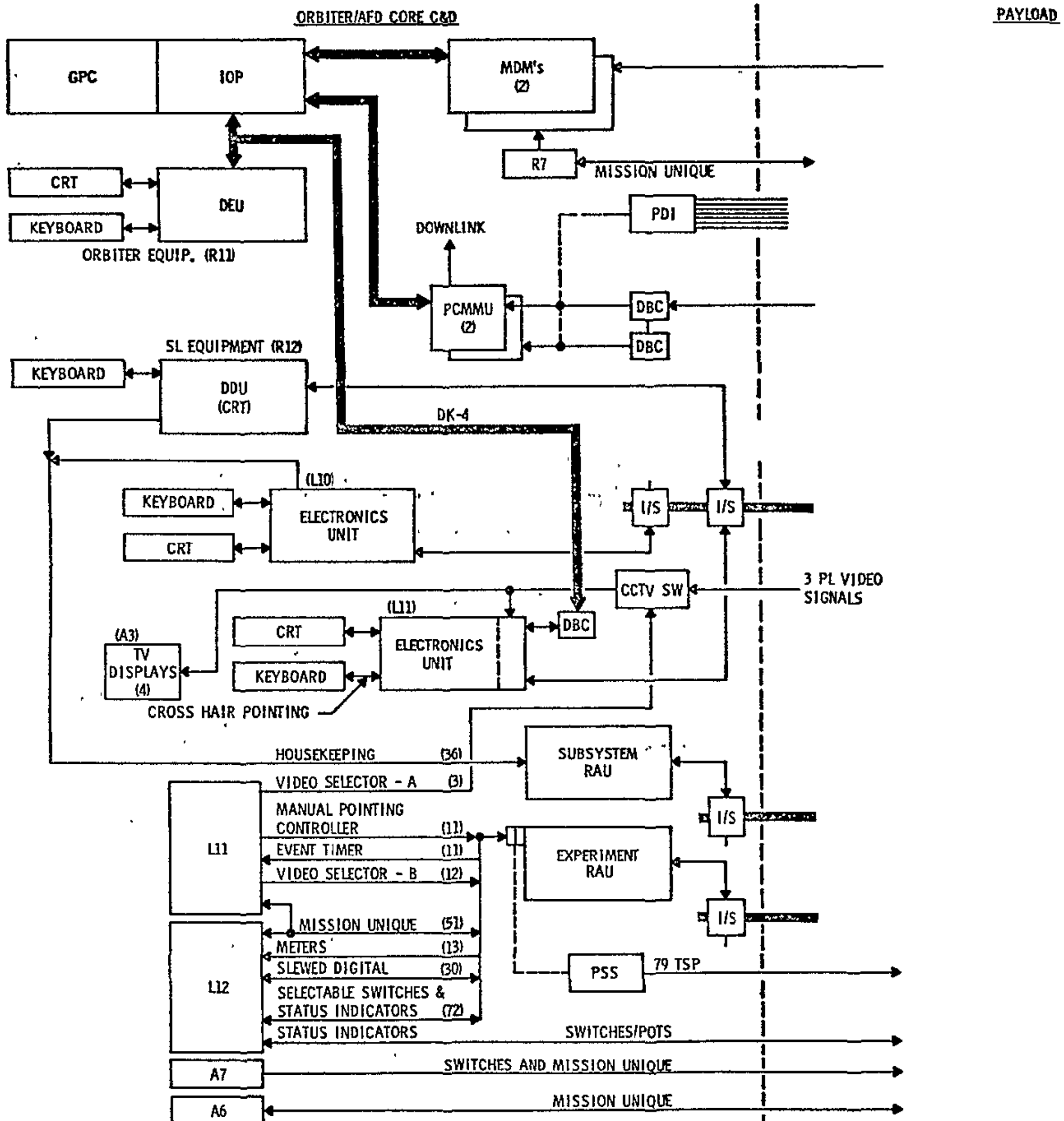

Figure 6-13 AFD CCD Total Free-Flyer/OFT Interface Capability

6.3 Hardware Interfaces - The core C&D panels all mount within the standard 19-inch racks provided by the Orbiter. Four of the panels (L10, L11, L12, and R12) occupy a full rack module (19-inches wide x 21-inches high x 20-inches deep), and the on-orbit station rack (A7) occupies a smaller volume (19-inches wide x 14-inches high x 8.0 to 9.5-inches deep). The volume behind the panel surfaces houses electronics associated with the C&D (e.g., display electronics, recorder electronics, experiment RAU, etc.).

6.3.1 Power Summary - The power utilized by the core C&D hardware is summarized in Table 6-1. This table identifies the power required by STS qualified equipment: a Spacelab Display Unit at panel L10, and an Orbiter Display Unit at panel L11. If the MFDS consists of the development of new hardware, considerably less power will be required: one electronics unit will support the two display units; in addition, low power circuits are now available for use in the power supply. The power requirements listed represent worst case conditions (all capital Ms).

Table 6-1 AFD Core C&D Power Requirements

PANEL	EQUIPMENT		POWER (watts) OPERATIONAL	POWER (watts) STANDBY
R12	Spacelab CRT/KB/DEU		290	50
L10	CRT/KB/EU		290	50
L11	CRT/KB/EU		313 (max)	20
	Event Timers		14	--
	LEDs (Legends)		10	--
L12	Spacelab Recorder: (Exp. RAU Required, 25W)	Record	101	46
		Playback	186	
		Wind/Rewind	101	
	Status Indicator Flags (25)		8	--
	LEDs (Legends)		20	--
	Digital Displays		13	--

Since on-orbit power consumption by payload C&D in the AFD is limited to 750 watts average during any three-hour period, it is imperative that timelines be generated for each specific mission configuration to determine the most efficient use of AFD C&D. Various combinations of C&D may be utilized to satisfy a particular mission. The appropriate combination can be chosen to keep power consumption within the 750 watts average for any three-hour period. Table 6-2 presents a listing of the possible component utilization combinations, and the corresponding power totals. It should be noted that the figures quoted are a worst case analysis.

Figure 6-14 shows an example of a power timeline for the Astronomy Facility mission, and indicates how such an analysis can be used to insure power constraints are not exceeded. Two three-hour power averages are shown, with the overall average power required being 695 watts. Maximum power required is 958 watts during the fourth hour of the sequence. As depicted in Figure 6-15, 958 watts may be provided by the Orbiter for 43 minutes without violating Orbiter power constraints.

6.3.2 Wiring Interface Design Summary - The preliminary AFD wiring design consisted of determining the quantity and type of wires required to support each candidate component considered for the AFD controls and displays concept. It also consisted of determining the quantity and type of wires available for payload use from the existing Orbiter wiring design, which included determining the wiring between the three AFD stations (PS, MS, OOS), the MS station and the bulkhead and the PS station and the bulkhead. The preliminary AFD wiring design then consisted of specifying the wiring required to support a controls and displays concept within the constraints imposed by the Orbiter system design and the component wiring requirements. The wiring design specifies the wiring between all items of core and mission-unique C&D hardware, and specifies wiring to the bulkhead for all core and mission-unique hardware located at panels L10, L11, L12, A6, A7, and R12. It also identifies that wiring which is utilized for Spacelab activation and available for payload use on non-Spacelab flights. The

Table 6-2 AFD C/D Power Combinations - Watts

R-12	L-10	L-11		L-12		AFD C/D	CAPABILITY
		CRT	TIMERS	RECORDER	STATUS		
ON 290	ON 290	ON 313	ON 14	PLAYBACK 186	ON 5	1,098	Maximum Power Combination
ON 290	ON 290	ON 313	ON 14	RECORD 101	ON 5	1,013	Full Up, Record
ON 290	STBY 50	ON 313	OFF	OFF	OFF	653	Exp. Setup + Pointing
ON 290	STBY 50	ON 313	ON 14	RECORD 101	ON 5	773	1 Data Plot + Video + Record
ON 290	ON 290	STBY 20	ON 14	RECORD 101	ON 5	720	2 Data Plots + Record
STBY 50	ON 290	STBY 20	OFF	PLAYBACK 186	OFF	546	Exp. Setup + Data Dump
ON 290	STBY 50	ON 313	ON 14	PLAYBACK 186	ON 5	858	1 Data Plot + Video + Data Dump
ON 290	ON 290	ON 313	ON 14	STBY 46	ON 5	958	Full Up, Recorder Not Required

NOTES:
1) 750 W average power allocation
2) 1000 W peak, 15 min during 3 hour period
3) Mission unique C/D must be added, if required

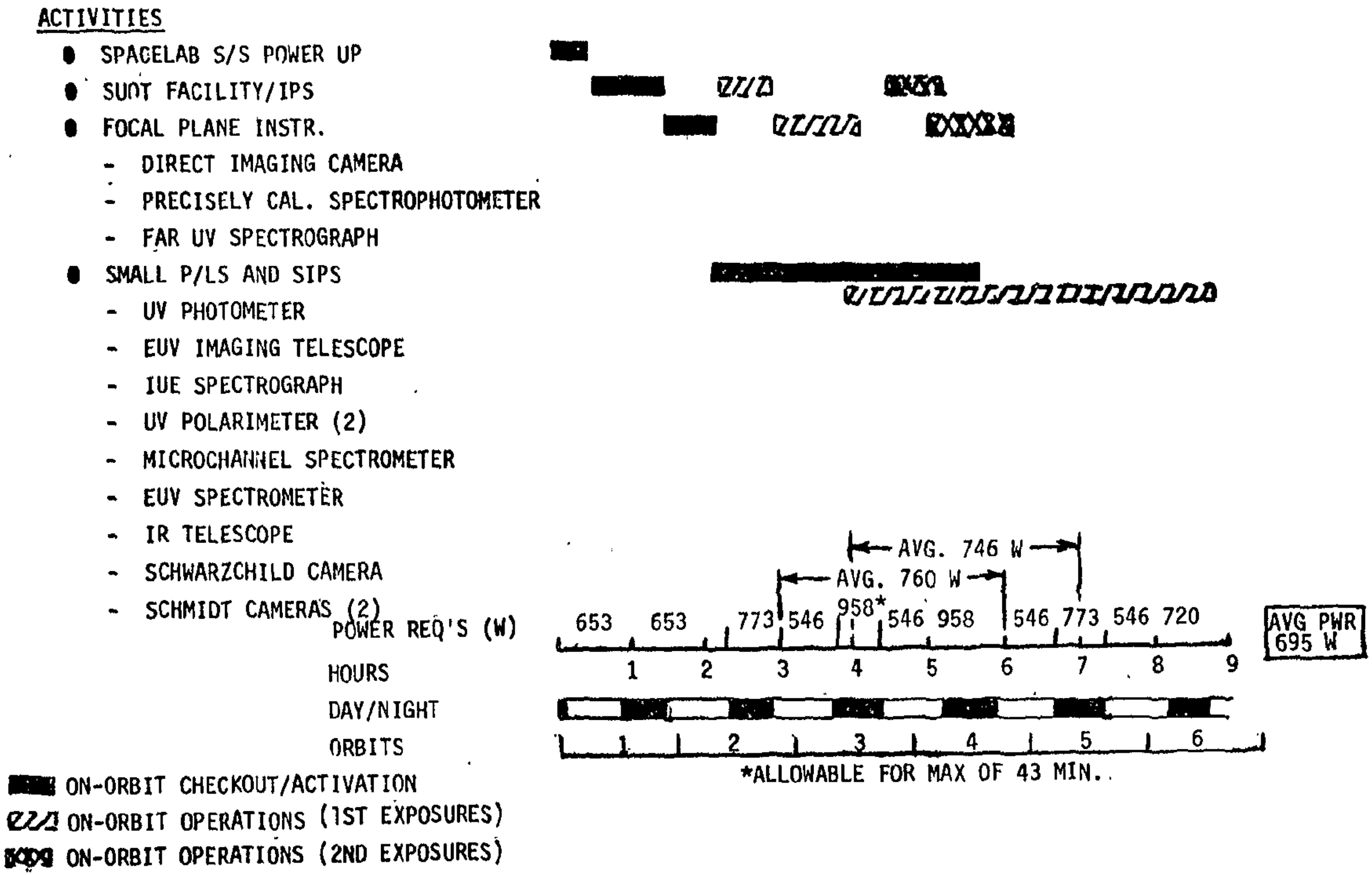

Figure 6-14 Astronomy Mission - Timeline

TIME ALLOWABLE AT GIVEN PEAK POWER IN AFD

NOTE: AVERAGE POWER MUST BE $\leq$ 750 W FOR ANY 3-HOUR PERIOD

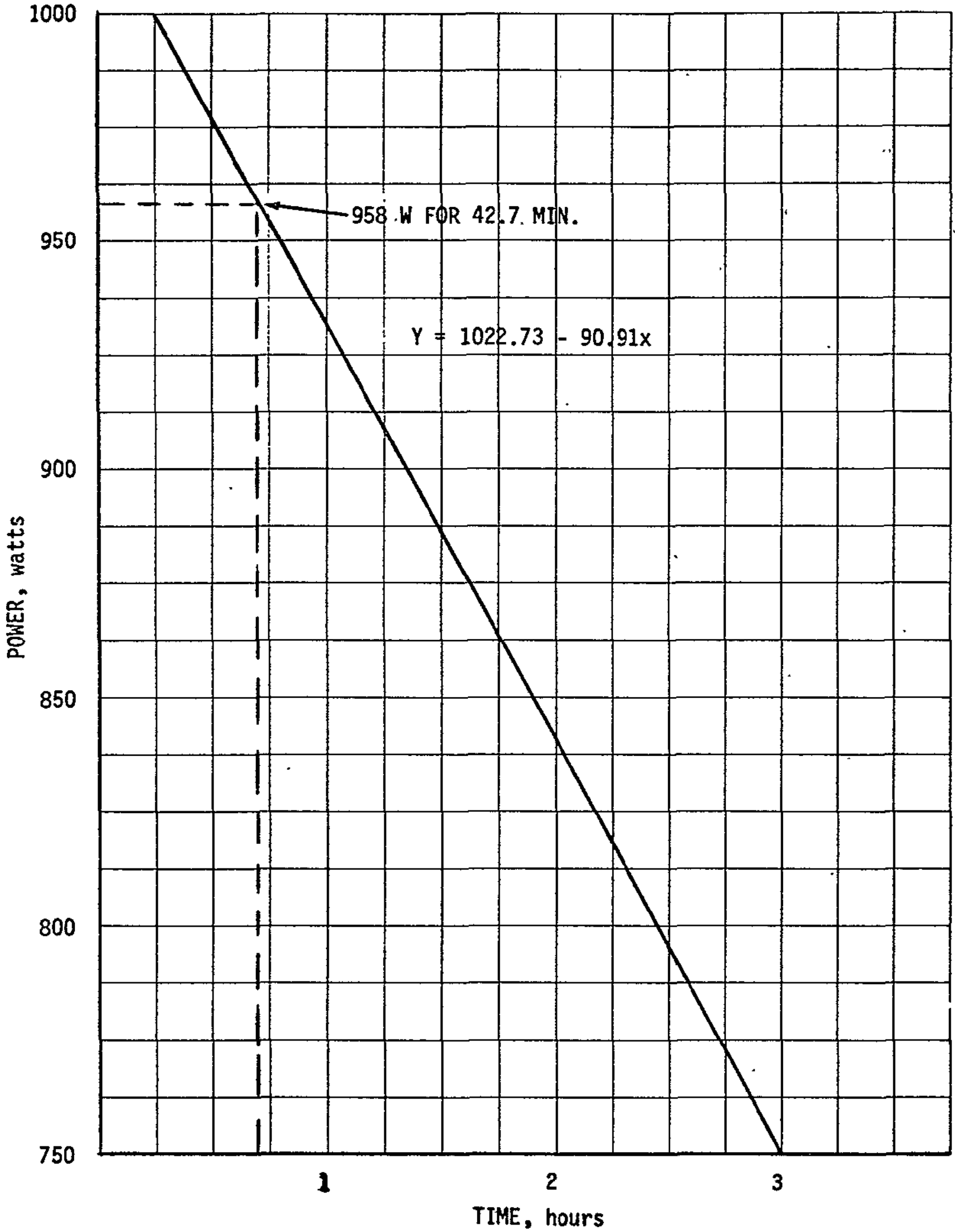

Figure 6-15 Peak Power Time Limits in AFD

wiring design made the most efficient utilization of payload-dedicated wiring such that spare wires would exist for future mission-unique hardware.

Two AFD payload wiring designs are shown in Figures 6-16 through 6-28. Figures 6-16 through 6-22 depict STS equipment utilizing both an experiment and subsystem RAU. Figures 6-23 through 6-28 show a new development MFDS using a subsystem RAU. An experiment RAU is required to support MMSE at panel L12 and payload mission-unique equipment at L11. The AFD wiring summary is shown in Figures 6-16 and 6-23; identified is the payload wiring provided by the Orbiter design and that required by the AFD core C&D hardware. The wiring is broken down into three types (twisted shielded pairs, twisted pairs, and coax). Wiring between the MS, PS, OOS, and the bulkhead is shown. Also the wiring required for Spacelab activation is shown in parentheses. The difference between the wiring provided and that required represents the spare wires available for mission-unique hardware.

The spare wiring from the PS to the bulkhead consists of 79 TSP and four TP. This spare wiring can support mission-unique hardware at the PS.

The AFD wiring interfaces are shown in Figures 6-17, 6-18, 6-24 and 6-25. Figures 6-17 and 6-24 show the wiring required between the various panels on the three stations (PS, MS, OOS) and the bulkhead. These figures also show the wiring interface to the RAU, which is required for the MMSE on panels L12 and L11 and the Spacelab CRT and keyboard on panel R12. Figures 6-18 and 6-25 show the data bus wiring interfaces. The CRTs and keyboards at the various panels address either the Spacelab experiment or subsystem buses via Interconnect Stations (I/S) as shown.

The wiring interfaces for the individual panels (L12, L11, L10) at the PS are shown in Figures 6-19 through 6-21 and Figures 6-26 through 6-27. These figures show the wiring interface with the RAU or hardwired to the bulkhead. Also shown is the quantity and type of wire required by the various components on the particular panels. The interface between the subsystem RAU and panel L10 is required if a Spacelab CRT and keyboard is used. If a MFDS is used, this interface is not required.

The Spacelab experiment RAU wiring interface is shown in Figures 6-22 and 6-28. The total capability of the RAU is shown along with the RAU interface wiring required

STS EQUIPMENT WITH EXPERIMENT AND SUBSYSTEM RAUs AT PSS

	MSS WIRING		PSS WIRING		PSS↔MSS
	TO BULKHEAD	TO OOS	TO OOS	TO BULKHEAD	WIRING
TSP	44/13 + 31 REQ. FOR R-7	43/39 + 2 REQ. FOR R-7	43/30 + 2	94/15	4/4
TP	30/5 + 25 REQ. FOR R-7	15/5 + 2 REQ. FOR R-7	15/12* + 2	88/84	0/0
COAX	0/0	0/0	4/0	3/0	3/0

NOTES: 1) WIRING SHOWN IS BASED ON APPROVED WIRING MODIFICATION PCIN S02878.

2) EMERGENCY SL IPS PANEL CAN BE ACCOMMODATED AT A6.

*SUPPORTS 12 TWO-POSITION LOCKED SWITCHES AT A7.

Figure 6-16 AFD Payload Wiring Summary (Available/Required)

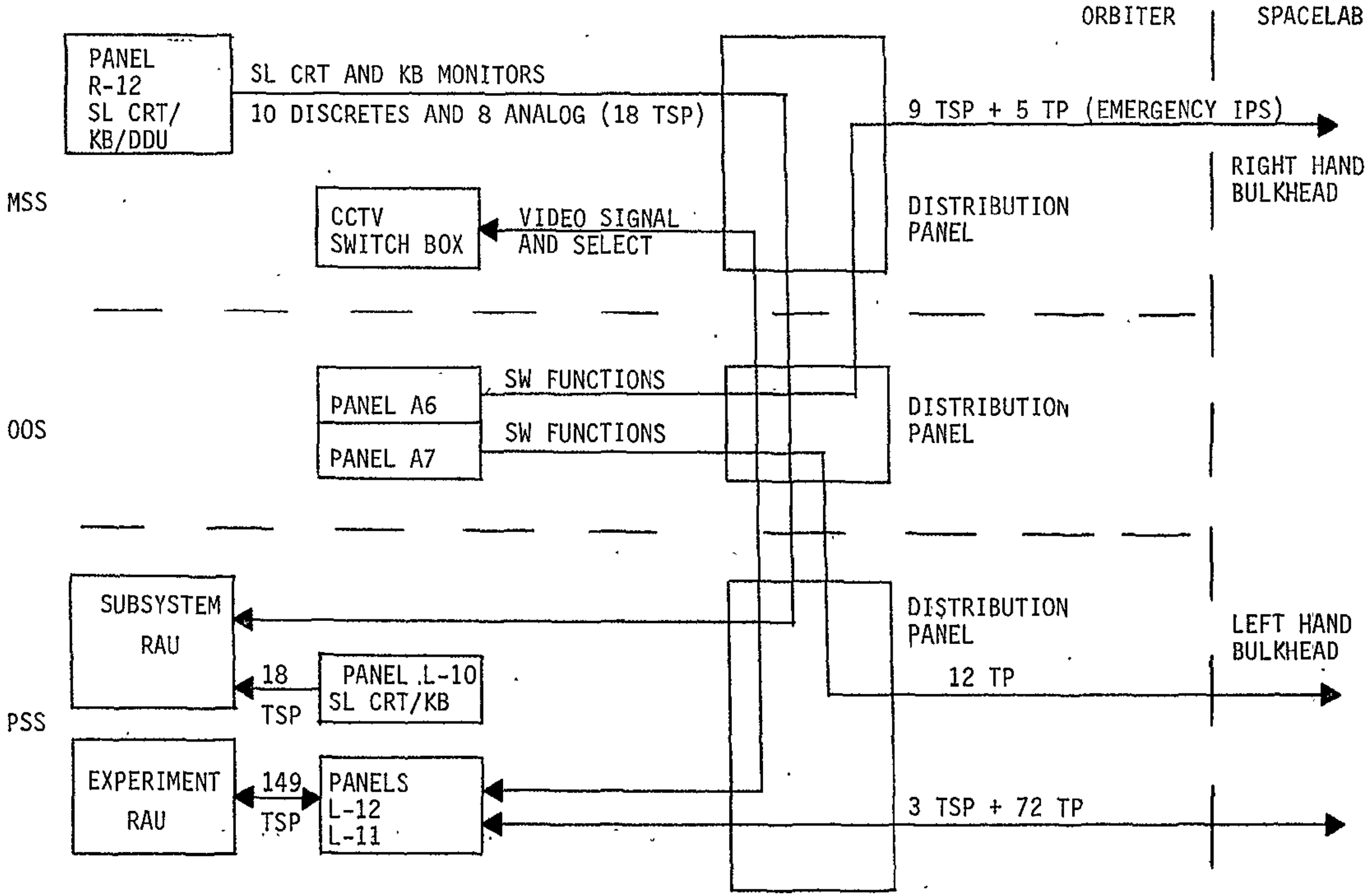

Figure 6-17 AFD Payload Wiring Interfaces

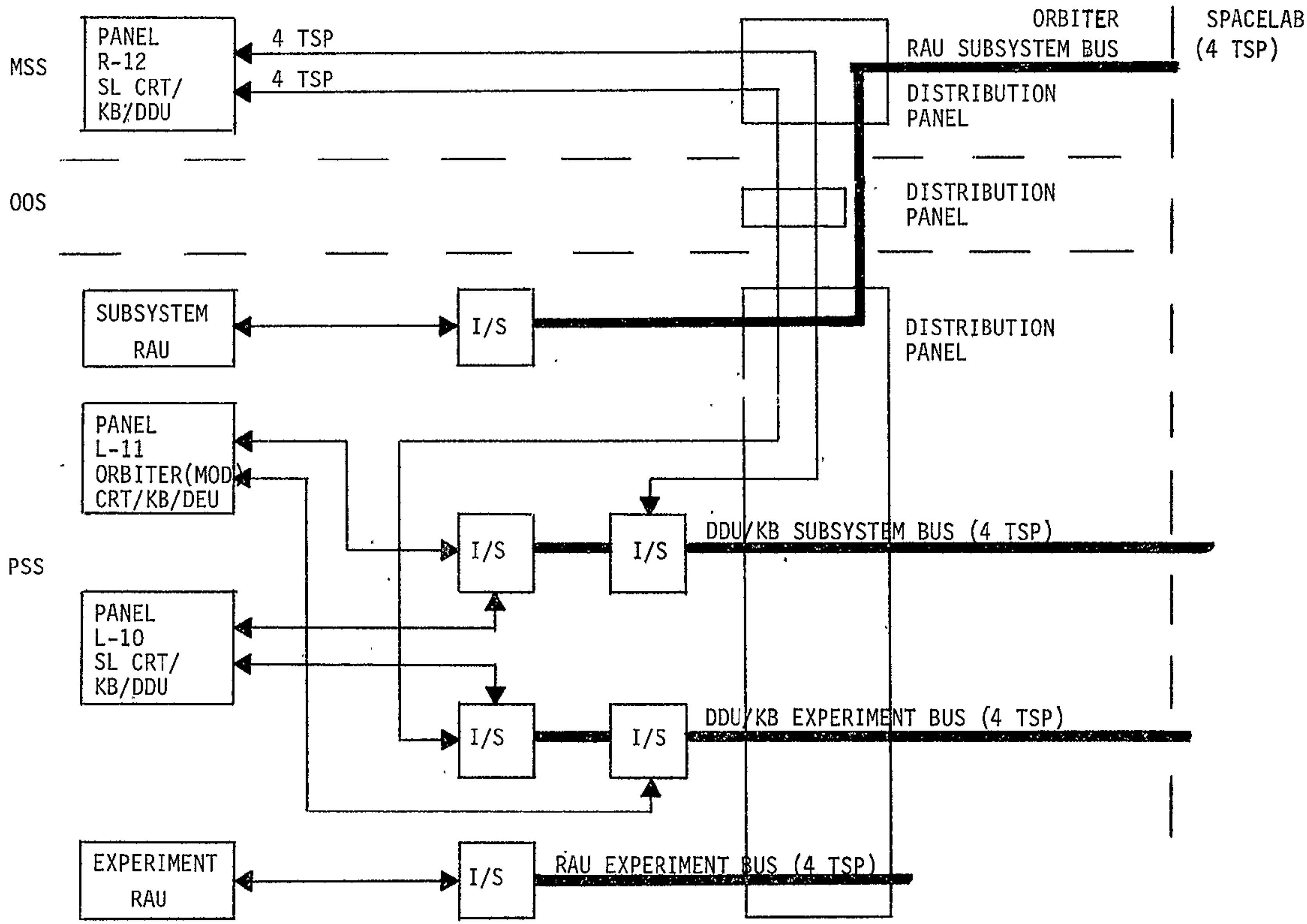

Figure 6-18 AFD Payload Wiring Interfaces (Data Buses)

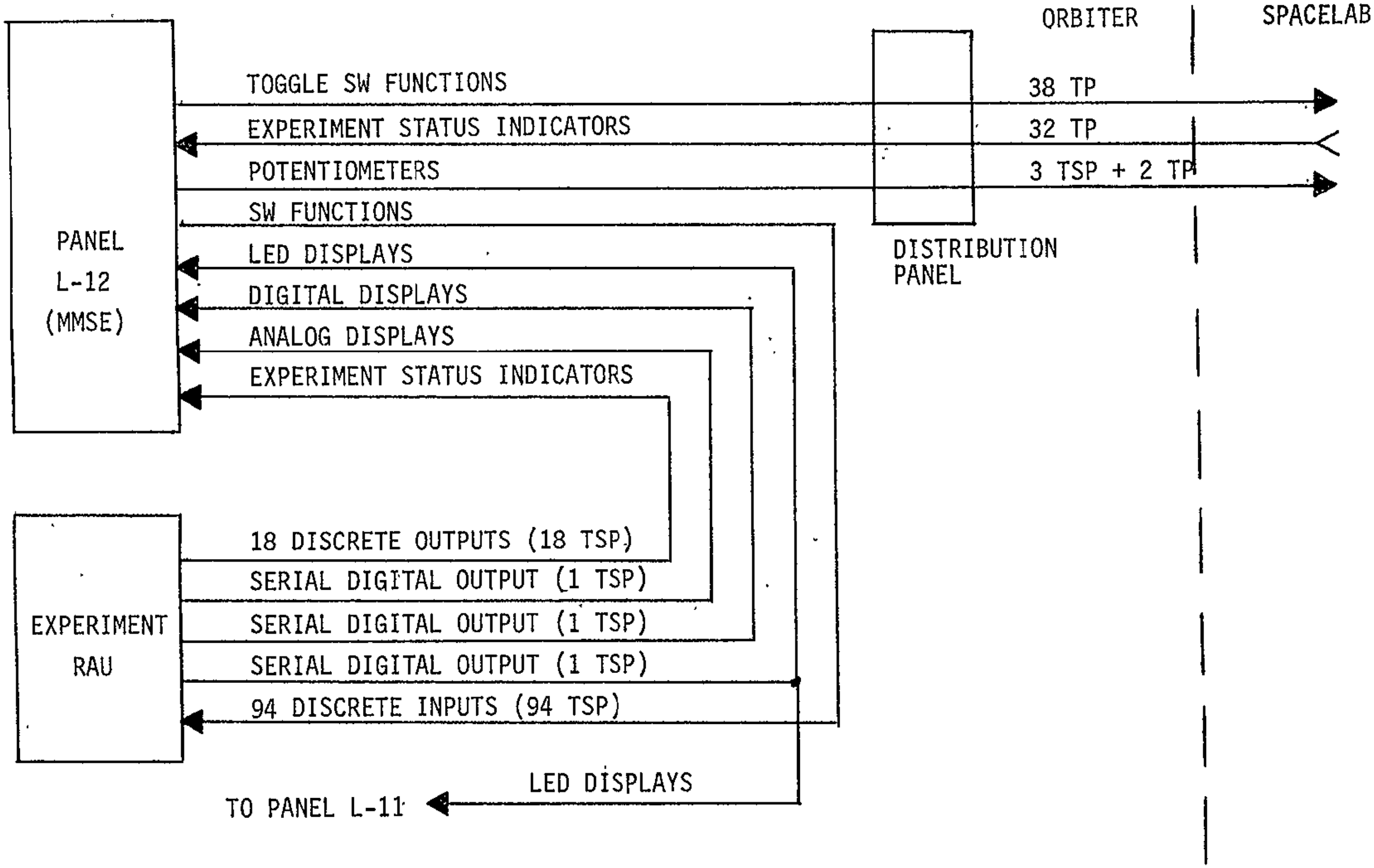

Figure 6-19 Panel L-12/RAU/Spacelab Interfaces

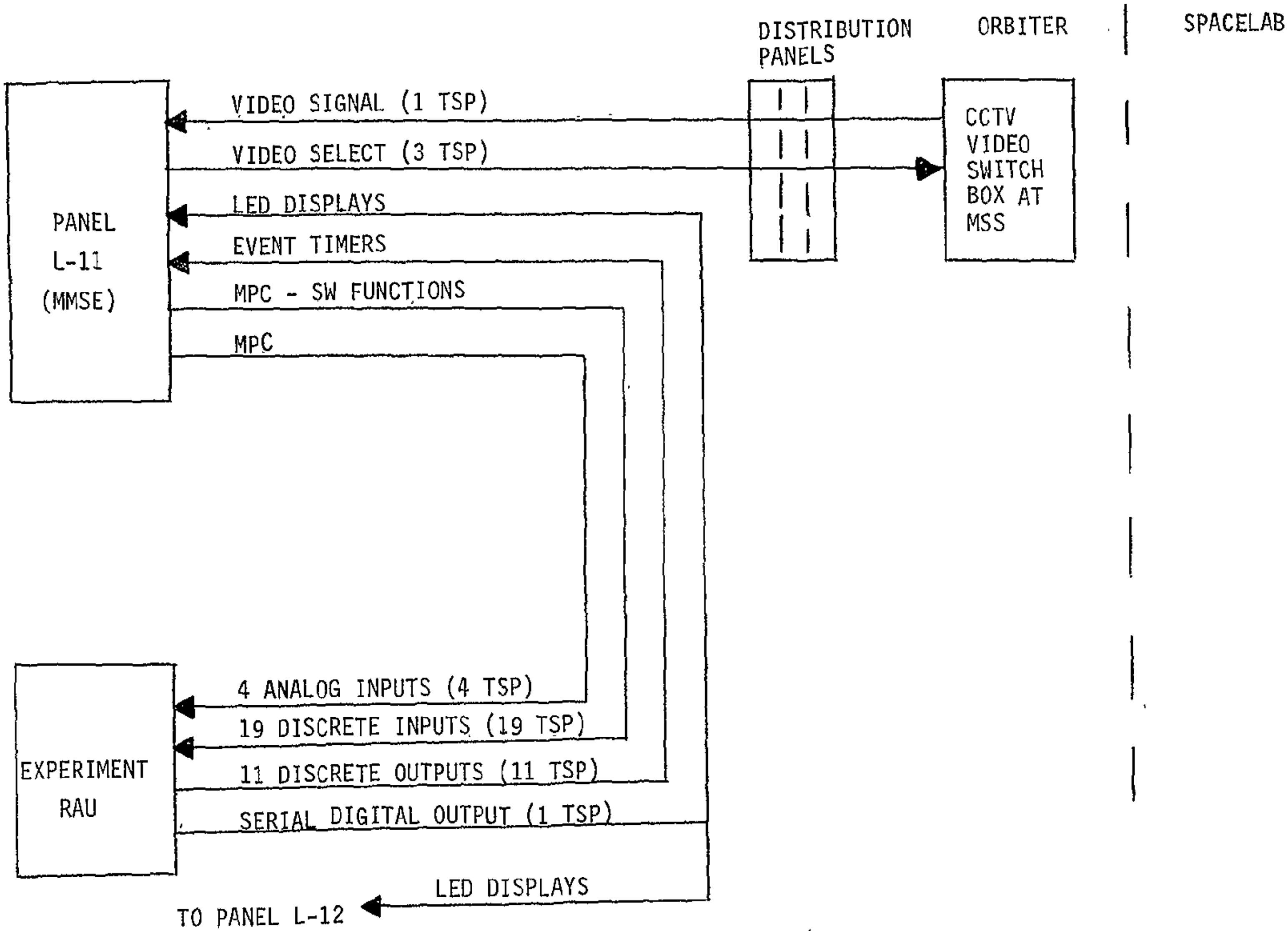

Figure 6-20 L-11/RAU/Spacelab Interfaces

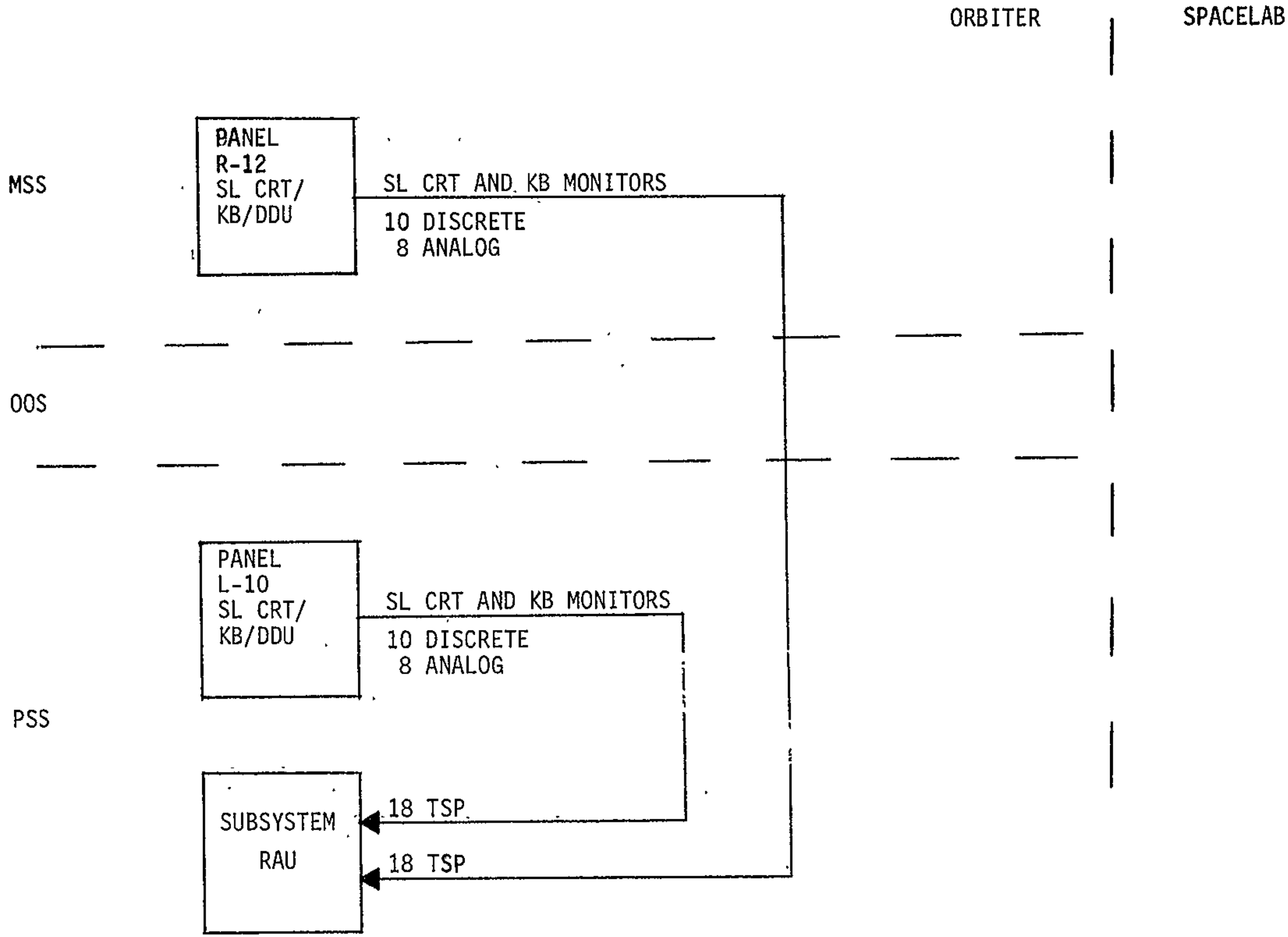

Figure 6-21 Panel L-10 and R-12/RAU Interfaces

EXPERIMENT RAU CAPABILITIES

DISCRETE INPUTS
ANALOG INPUTS

128 SOFTWARE SELECTABLE MIX OF ANALOG OR DISCRETE INPUTS

DISCRETE OUTPUTS - 64

SERIAL DIGITAL OUTPUTS - 4

SERIAL DIGITAL INPUTS - 4

EXPERIMENT RAU REQUIREMENTS

	L-12	L-11	MISSION UNIQUE SPARES (L-11)	TOTAL
DISCRETE INPUTS	94	19	11	124
ANALOG INPUTS	0	4	0	4
DISCRETE OUTPUTS	18	11	35	64
SERIAL OUTPUTS	3	0	1	4
SERIAL INPUTS	0	0	4	4

Figure 6-22 AFD RAU Requirements/Capabilities (Experiment)

MFDS (NEW DEVELOPMENT) WITHOUT EXPERIMENT RAU AND WITH SUBSYSTEM RAU AT PSS

	MSS WIRING		PSS WIRING		PSS ↔ MSS
	TO BULKHEAD	TO OOS	TO OOS	TO BULKHEAD	WIRING
TL	44/13 + 31 REQ. FOR R-7	43/39 + 2 REQ. FOR R-7	43/30 + 2	94/15	4/4
TP	30/5 + 25 REQ. FOR R-7	15/5 + 2 REQ. FOR R-7	15/12* + 2	88/84	0/0
COAX	0/0	0/0	4/0	3/0	3/0

NOTES: 1) WIRING SHOWN IS BASED ON APPROVED WIRING MODIFICATION PCIN S02878.

2) EMERGENCY SL IPS PANEL CAN BE ACCOMMODATED AT A6.

* SUPPORTS 12 TWO-POSITION LOCKED SWITCHES AT A7.

Figure 6-23 AFD Payload Wiring Summary (Available/Required)

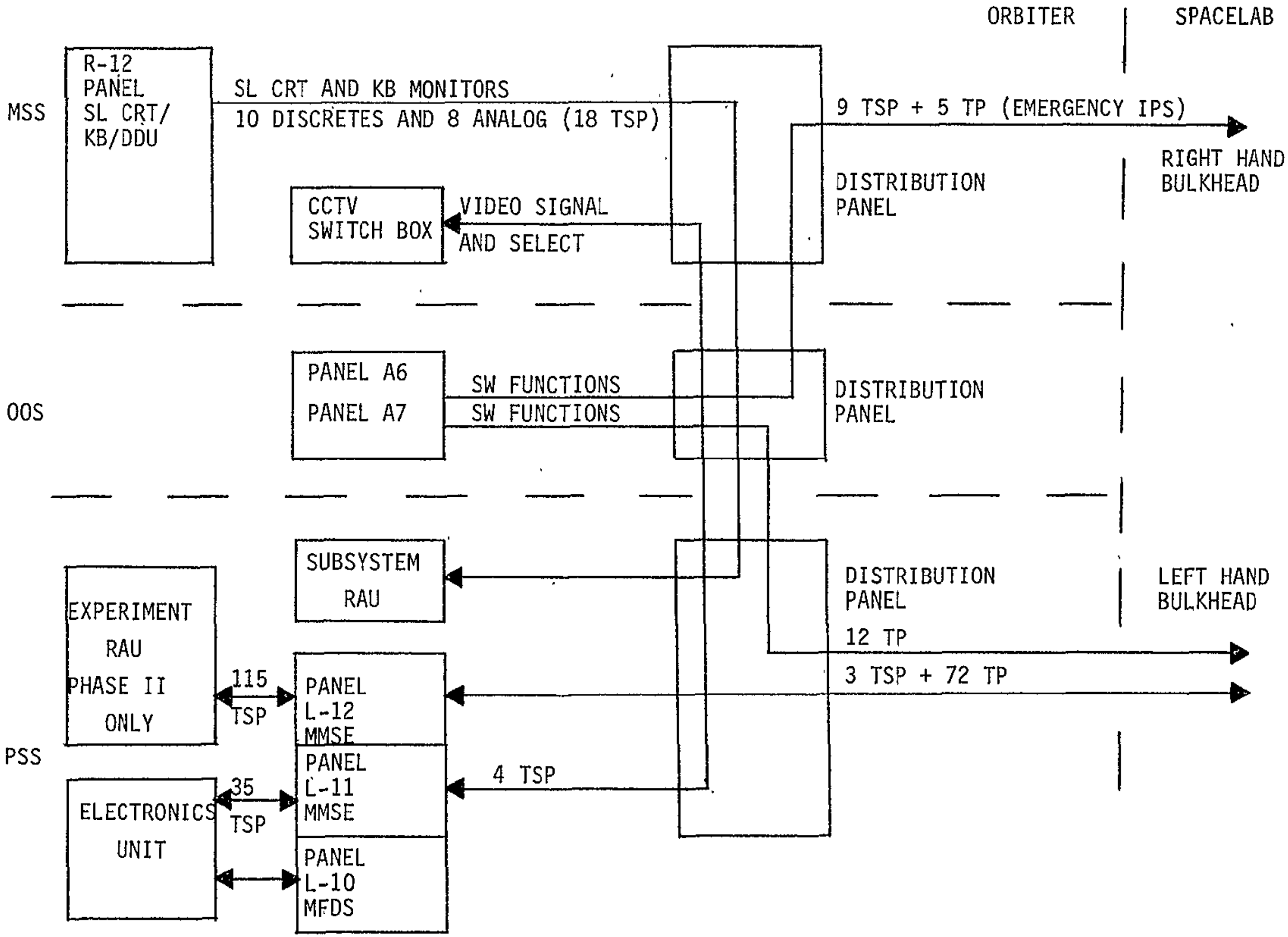

Figure 6-24 AFD Payload Wiring Interfaces

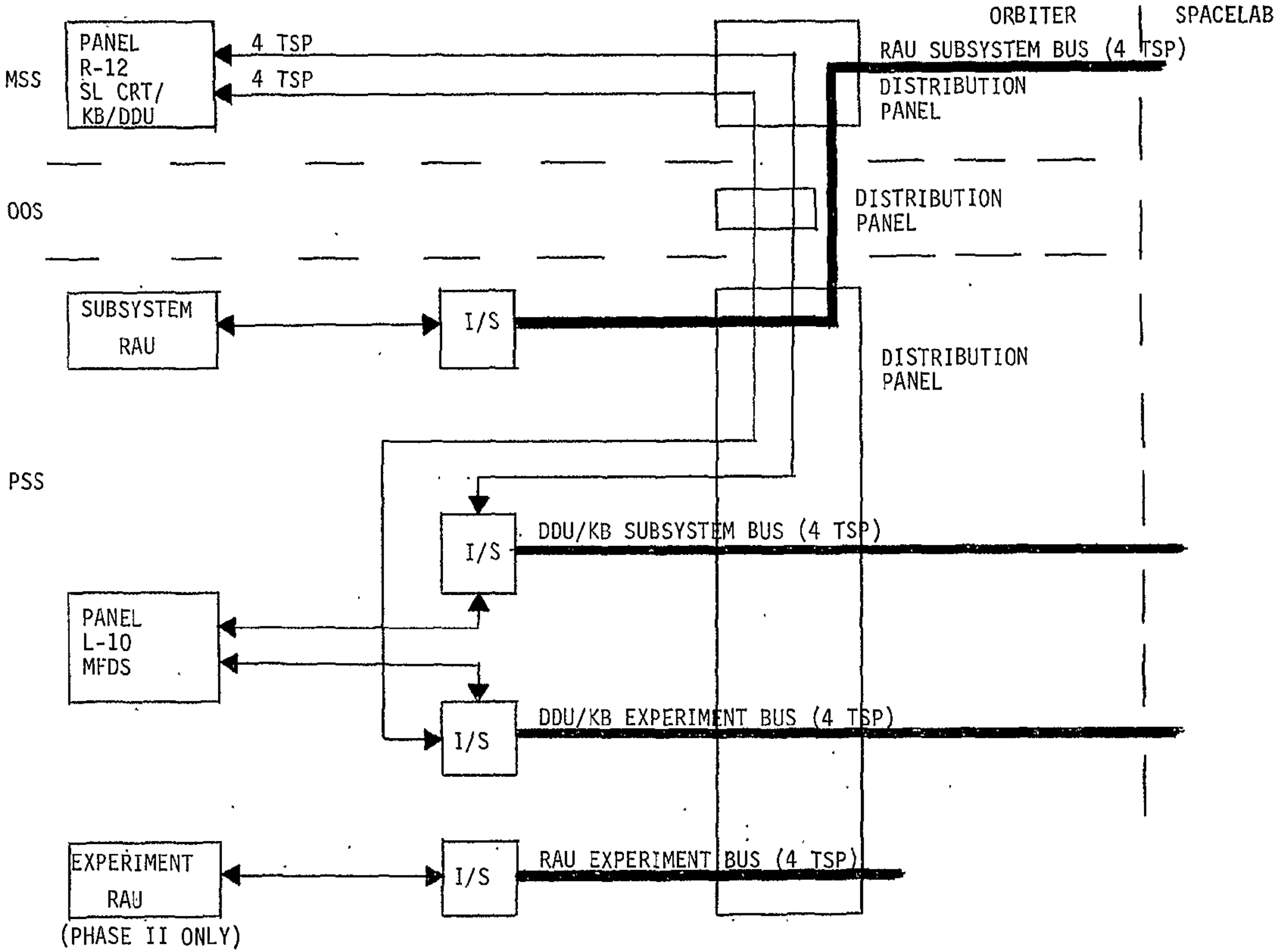

Figure 6-25 AFD Payload Wiring Interfaces (Data Buses)

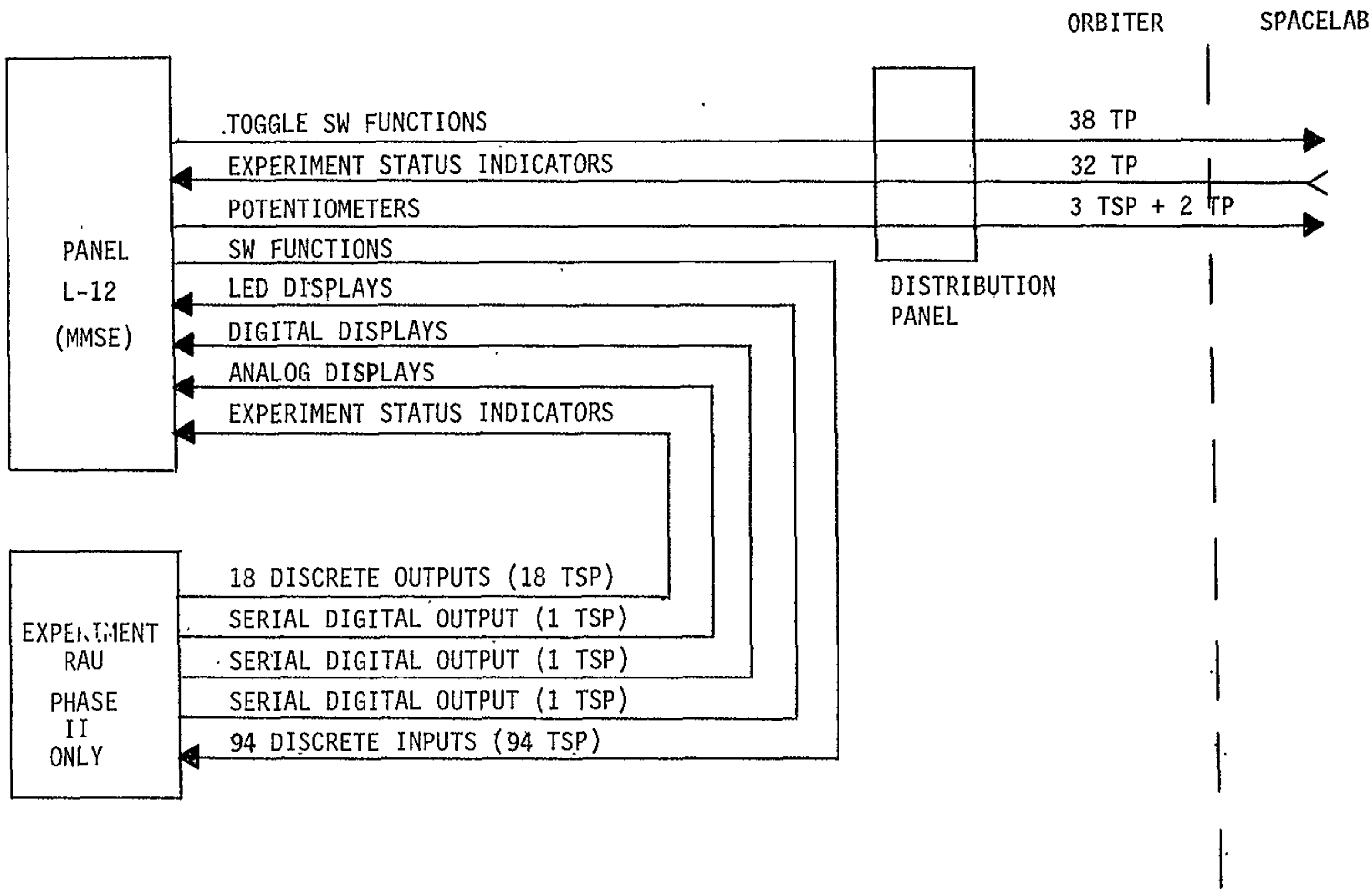

Figure 6-26 L-12 Panel/RAU/Spacelab Interfaces--Phase II Only

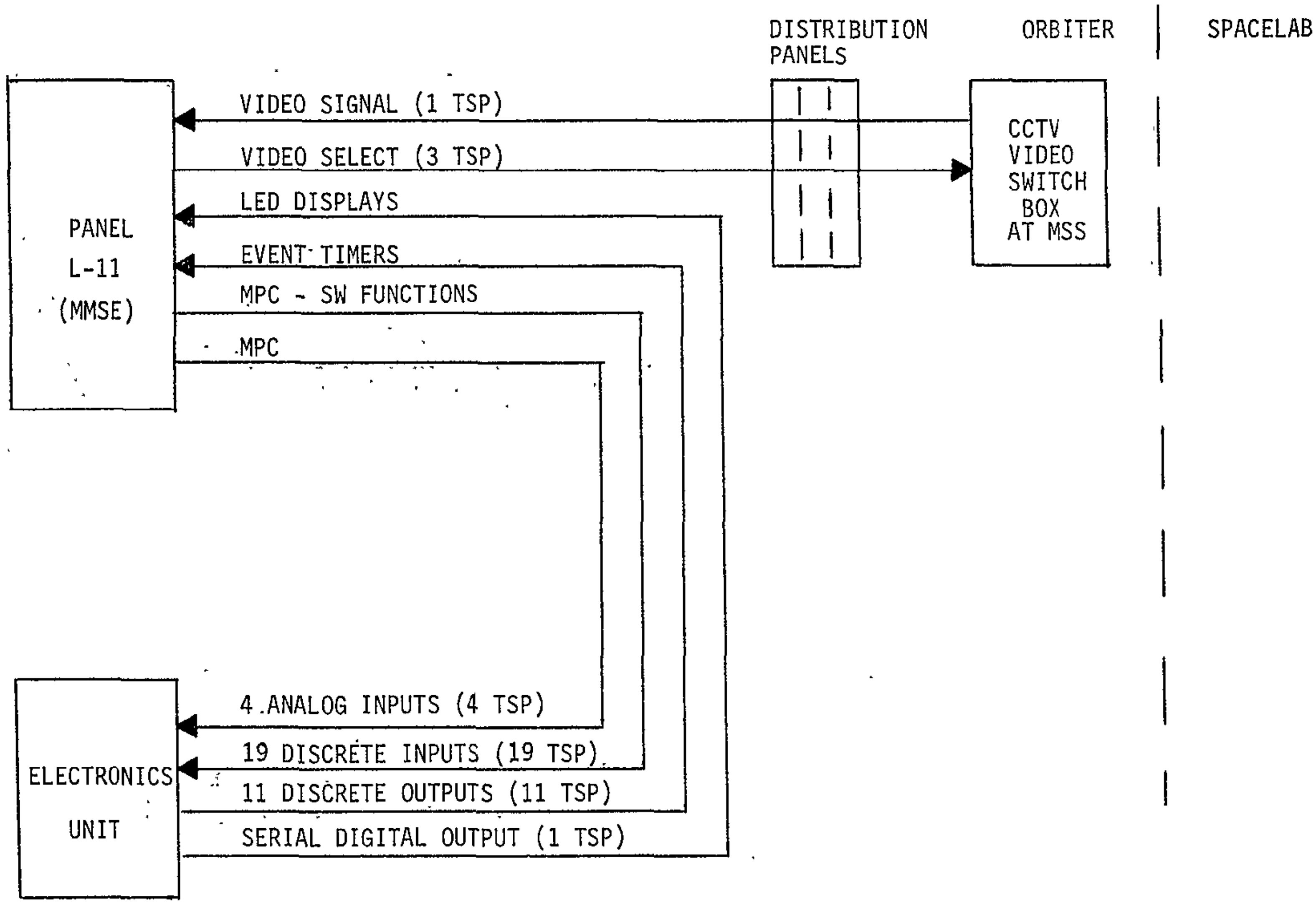

Figure 6-27 L-11 Panel/RAU/Spacelab Interfaces

EXPERIMENT RAU CAPABILITIES

DISCRETE INPUTS ANALOG INPUTS	128 SOFTWARE SELECTABLE MIX OF ANALOG OR DISCRETE INPUTS

DISCRETE OUTPUTS - 64

SERIAL DIGITAL OUTPUTS - 4

SERIAL DIGITAL INPUTS - 4

EXPERIMENT RAU REQUIREMENTS

	L-12	MISSION UNIQUE SPARES (L-11)	TOTAL
DISCRETE INPUTS	94	30	124
ANALOG INPUTS	0	4	4
DISCRETE OUTPUTS	18	46	64
SERIAL OUTPUTS	3	1	4
SERIAL INPUTS	0	4	4

Figure 6-28 AFD RAU Requirements/Capabilities (Experiment)--Phase II Only

for the various panels. The unused RAU capability is available for mission-unique hardware at panel L11.

The cabling between the payload station and distribution panel is defined in the following paragraphs. The wiring required between panels L10, L11, L12, and the PS distribution panel consists of control and display functions which are either hardwired to the bulkhead or are routed to the OOS and MS. This wiring is not part of the Orbiter design and therefore is specified in this study. The Orbiter design has provided wiring from the PS distribution panel to the on-orbit station, the bulkhead, and Orbiter systems.

The distribution panel at the payload station is made up of 20 connectors which contain either payload dedicated and/or Orbiter wiring, as defined by the Orbiter system design. Nine of the 20 connectors contain payload dedicated wiring--four of which contain both payload-dedicated and Orbiter wiring. The remaining five connectors contain payload-dedicated wiring only.

The cabling between panels L10, L11, and L12 and the PS distribution panel was designed to provide the following capabilities--to be able to remove Spacelab equipment and associated cabling on non-Spacelab flights without impacting Orbiter wiring; to add mission-unique wiring in support of mission-unique C&D without impacting Orbiter or core wiring.

The PS to distribution panel cabling schematic is shown in Figure 6-29.

Core C&D wiring which will not change from mission to mission is wired to connectors in the PSS distribution panel which also contain Orbiter wiring. The core C&D wiring, which may be removed on non-Spacelab flights, is wired to connectors which contain payload-dedicated wires only. Seventy-nine wires from the distribution panel through the bulkhead are available to support mission-unique C&D at panels L11 and L10. This wiring may be utilized at any time without impacting either Orbiter or core wiring.

6.3.3 <u>Weight Summary</u> - The weight allocated for each panel at the PS and MS is a maximum of 150 lbs. Fifteen (15) lbs are used by the panel structures. All panels associated with the AFD core C&D weigh substantially less than 135 lbs. L12 is the heaviest panel, weighing 92.8 lbs when the recorder is

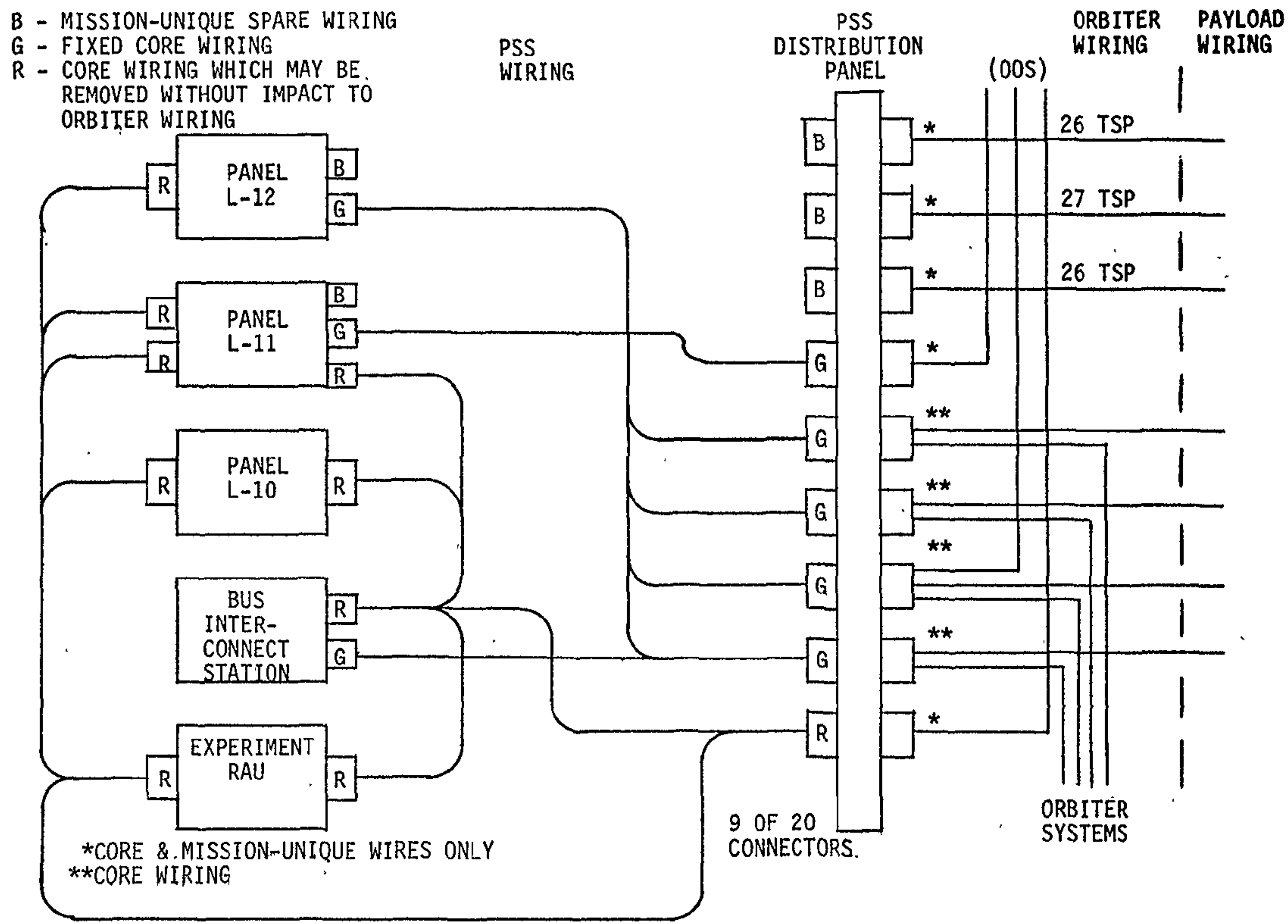

Figure 6-29 PSS Cabling and Connector Schematic

in place. Table 6-3 summarizes component weights for the AFC core C&D.

Table 6-3 PSS Core Equipment Weight Breakdown

PANEL L12		PANEL A7	
1 Spacelab Recorder/MMSE	83.0/31.0	12 Locked Switches	1.0
14 Toggle Switches	2.8	Cabling and Structure	2.5
10 Status Indicators	2.0	Total	3.5
Cabling and Structure	5.0	Total All Panels (L12, L11, L10, A7)	250.0 lbs
Total	92.8		
PANEL L11		SPACELAB EQUIPMENT (138 lbs)	
1 Display Unit, DEU, Keyboard	66.0	Spacelab DU, DEU, Keyboard at R12	
2 Event Timers	2.0	Spacelab Emergency IPS Panel at A6	
1 Manual Pointing Controller	3.0	2 RAU's and PDB at PSS	
10 Toggle Switches	2.0	Spacelab Activation at R7	
2 Potentiometers	0.5	Cabling and Structure	
1 Rotary Switch	0.2		
Cabling and Structure	5.0	NOTE: Each panel less than 135 lbs allocated	
Mission-Peculiar Equipment	~5.0		
Total	83.7		
PANEL L10			
1 Display Unit, DEU, Keyboard	65.0		
Cabling and Structure	5.0		
Total	70.0		

6.4 Part I CEI Specifications - Contract End Item (CEI) specifications have been completed for the core C&D, applicable software, and for the ground support equipment (GSE) required by the core equipment. Five separate CEIs have been generated--one each for the multifunction display system portion of the core, the multi-use mission support equipment, the software requirements of the core, and the GSE. The following paragraphs briefly describe the contents of the CEIs, which are contained in full in Volume II, Part II of this final report.

6.4.1 Multifunction Display System (MFDS) Specification - The MFDS Part I CEI Specification is written so as not to preclude use of either STS qualified hardware with modifications or a new development. This specification will be used by a contractor to purchase MFDS equipment in a phase C/D contract.

The multifunction display system (MFDS) is located at the Payload Specialist Station (L10 and L11) and consists of two CRTs and one or two keyboards with associated electronics units. The MFDS is the primary method the payload specialist will use to perform experiment setup and display experiment data. He will use the MFDS to assist in such tasks as experiment activation, setup, and calibration. The payload specialist will also perform the experiment and monitor data taken using the MFDS. He will be able to point telescopes, display data plots, monitor experiment status, etc.

The MFDS Part I CEI Specification includes the following as items of special interest. A full alphanumeric KB plus special function keys shall be provided. One of the two CRTs will have the capability to display video, alphanumeric data, and graphics. The graphics and alphanumerics will be able to overlay a video picture. This CRT has the capability to display either a 512-line video picture or a 1,000-line video picture. The second CRT shall be capable of a tri-color (green, yellow, red) display of alphanumerics, graphics, and graphics overlays.

To assist with experiment pointing the MFDS shall provide the means to electronically generate cross hairs on the CRT. The payload specialist will position the cross hairs over the event of particular interest and then command the instrument to slew to this point of interest.

The specification also specifies that the built-in test equipment shall be capable of detecting at least 96% of single-solid failures. This can be achieved by utilizing MFDS self-checks, test programs, and operator interpreted test patterns.

The MFDS is required to interface with both the Orbiter data bus and with the Spacelab subsystem and experiment data buses. These interfaces are with the Orbiter and Spacelab computers. The MFDS will also be required to contain sufficient memory to support the core C&D software. This will reduce the amount of software stored in the Spacelab or payload computers.

6.4.2 Multi-use Mission Support Equipment (MMSE) Specification - The MMSE specification covers the controls and displays (with associated electronics), apart from the MFDS equipment, located at panels L11, L12, and A7. Table 6-4 lists the specific items for which requirements are detailed in the specification. The MMSE located on subpanels L12-A1, L12-A3, and the potentiometers on L12-A5 are all hardwired through the $X_0$576 bulkhead. The remaining MMSE is ordinarily wired to the experiment RAU at the PS for data bus control.

The specification defines MMSE performance requirements, interfaces, environments, operability, and human engineering requirements. All the MMSE components are standard, STS-qualified types of hardware and no new development is required.

6.4.3 Software Requirements Specifications

6.4.3.1 Flight Software CEI - The CCD software CEI will contain top level software requirements for communication with MMSE as well as display units and keyboards in the AFD. For the display and keyboards, alphanumeric, graphic, and video overlay requirements will be presented. For the MMSE software driven control and displays each function by subpanel, including the number of interface variables, will be defined. The detailed requirements spanning from the C&D hardware panels to the main computer command and status registers will be provided during the phase C/D contract. The main computer may consist of either an orbiter AP101, Spacelab M125S, or be payload provided. When fully implemented, the command and status registers in the main computer will become a simple interface with the mission-unique application software. The status registers will reflect the current status of all CCD switch command functions, and the command registers will allow the application software to set functions for subsequent display on the MMSE and display units (CRT).

Table 6-4 Part I MMSE CEI Equipment List

EQUIPMENT LOCATION	DESCRIPTION
L12-A1	• Two-Position Momentary Toggle Switches (13) • Three-Position Indicators (10) • Three-Position Toggle Switch (1)
L12-A2	• 12-Position Rotary Switch (2) • Two-Position Momentary Toggle Switch (2) • Legends (LEDs) (4) • Digital Displays (5-digit) (2)
L12-A3	• Two-Position Locked Toggle Switch (18) • Three-Position Indicators (6)
L12-A4	• Analog Meters (3) • 12-Position Rotary Switch (1)
L12-A5	• Potentiometers, Rotary (5) • 12-Position Rotary Switch (3) • Two-Position Momentary Toggle Switch (9) • Three-Position Indicators (9)
L11-A3	• Event Time Display, 4-digit (1) • Two-Position Momentary Toggle Switch (3) • Legend (LED) (1)
L11-A4	• Same as L11-A3
L11-A5	• 12-Position Rotary Switch (1) • Three-Position Toggle Switch (1) • Two-Position Momentary Toggle Switch (2) • Manual Pointing Controller (Pitch/Yaw) (Joystick) (1)
A7-A2	• Two-Position Locked Toggle Switch (12)

6.4.3.2 Ground Test Software CEI - This Part I CEI specification will define top level test sequence requirements which will allow fault isolation to the subpanel level for all AFD core C&D. The test sequence software will interface with a simple test sequence executive module which will respond to test sequence commands to issue signals, monitor status, write procedural text pages, and print summary results.

6.4.4 Ground Support Equipment (GSE) Specification - Ground support equipment (GSE) is required to perform acceptance testing of the MFDS. Prior to installation of this equipment into the Aft Flight Deck, GSE is required to verify the core C&D equipment during system integration both at KSC and MSFC.

The Part I CEI specification for GSE will be used by a contractor to purchase GSE equipment in Phase C/D. The GSE will consist of a minicomputer-based system (off-the-shelf, common commercial equipment) which can be made to interface with the core C&D in a manner similar to that of the flight computers.

The following major components comprise the GSE. A CRT/keyboard is required to select various test sequences, and display test results and parameters A line printer is required to make a permanent record of the test sequence and test results. Mass memory is required to store the procedural text and CRT test patterns, etc. The input/output equipment will interface the minicomputer to the core C&D and will simulate the hardware interface of the Spacelab computers.

The Spacelab data bus and core C&D interfaces shall be verified using GSE. Also all MMSE shall be verified through the GSE. The GSE will interface directly with the MMSE by simulating the Spacelab remote acquisition unit (RAU), thus making the checkout of the AFD core C&D independent of Spacelab equipment. The Spacelab CRT and keyboard at R12 and L10 will not be checked out with the GSE.

The GSE will be required to identify and isolate failures in the core C&D to a level which will facilitate easy replacement down to the card level for the MFDS and down to the subpanel level for MMSE.

7.0 DATA FORMATTING (TASK VII)

The objective of Task VII was to perform data analyses and organize data into formats to be included in the NASA STS Payload Planning Data Bank at MSFC. Outputs from Tasks III, IV and V were utilized to correlate the data relating to the proposed AFD concept, as details were generated.

Data formats were established in Task III (examples are shown in Tables 4-3, 4-4, and 4-5), when individual component characteristics were defined and DDT&E flows were identified. These formats included equipment identification, physical characteristics, operation cycles, program schedules, key performance characteristics, and interface data.

The concept selected in Task IV for preliminary design in Task V included as major components STS equipment, MMSE and new development hardware. Data formats already exist in the data bank for the STS hardware and the MMSE. It is anticipated that as the new development items are defined in more detail in Phase C/D, proper formatting of that component data will be maintained by the Phase C/D contractor.